Science teacher preparation: An assessment of the opportunities to learn and their effects on pre-service teachers' competence

David Maleho Letloenyane

Thesis submitted in accordance with the requirements

for the degree

Philosophiae Doctor

in

Curriculum Studies

Faculty of Education

University of the Free State

Supervisor: Professor L.C. Jita

January 2018

Declaration

I hereby declare that the work which is submitted here is the result of my own investigations and that all sources I have used or quoted have been acknowledged by means of complete references. I further declare that the work is submitted for the first time at this university towards a PhD in Education degree and it has never been submitted to any other university for the purpose of obtaining a degree.

I hereby cede copyright of this product to the University of the Free State.

……………………………………   ………………………………

DM LETLOENYANE   DATE

Acknowledgements

I thank my study leader, Professor Loyiso C. Jita for his guidance, support and encouragement. It truly is a privilege to work with you and to learn from your expertise. I will forever be indebted to you.

I acknowledge and thank the SANRAL Chair's support team led by Dr T. Jita for contributions made to the conceptualization and eventual implementation of the research study. I express my gratitude to Ms M. Molete-Mohapi for the excellent administrative support she provided. I also wish to show my appreciation to Prof Robert Schall of SCU for the invaluable advice and insights with regards to the statistical handling of the data. I can boldly declare that the only reason I have seen further is that I stood on the shoulders of giants.

This research study would not have been possible if it was not for the universities, lecturers and physical science pre-service teachers who afforded me their space and time in trying times. I am eternally grateful for the support you showed me in my hour of need.

My cohort members and fellow researchers who always availed themselves to provide constructive feedback on the drafts and ideas whenever called upon. I wish to acknowledge Prof M. Mokhele-Makgalwa and Drs C. Malinga, R. Gudyanga, C. Reju, M. Mosia and M. Tsakeni for interrogating my work throughout the duration of the study. Research tends to be a lonely road but you made the journey bearable and I thank you for that.

Great is Thy faithfulness!

Great is Thy faithfulness!

Morning by morning new mercies I see;

All I have needed Thy hand hath provided-

Great is Thy faithfulness, Lord, unto me!

Thomas Obediah Chisholm (1866-1960)

Dedication

This thesis is dedicated to my wife Puleng Letloenyane. Thank you for the understanding and support you afforded me. You walked every step of the way with me during this journey. Most of all, thank you for your unwavering belief even when I started to doubt the feasibility of this study.

To my daughters Atlegang and Tlotlegang. At times, I did not have time to be what a father should be to his daughters. Thank you for your patience and understanding.

To the Letloenyane family and other immediate families. It is only through your sacrifices and prayers that I am what I am today. *Ke a leboga Bahurutshe Bo Manyane.*

Table of Contents

List of Tables

List of Figures

Summary of the study

Science teacher preparation: An assessment of the opportunities to learn and their effects on pre-service teachers' competence

Teacher education institutions are important because they are tasked with preparing teachers who will in turn prepare future professionals. Although these institutions have been preparing teachers for decades, the manner in which teacher education contributes to teacher competence is not thoroughly captured in the literature. Studies have been conducted in initial teacher education to link teacher education and teacher competence, but few scholars attempt to study the effects of teacher training holistically. The current study therefore investigated the relationships between opportunities to learn (OTL) that pre-service teachers (PST's) are afforded in their teacher education programmes and aspects of PST's competence. Specifically, this study sought to determine OTL that are predictors of multiple pre-service physical science teachers' knowledge and belief bundles. The assumption is that these OTL may form the basis of effective science teacher preparation programmes and therefore, lead to competent novice physical science teachers.

This quantitative study used a questionnaire which consisted of knowledge, beliefs and OTL sections to collect data from 112 final year pre-service science teachers from four universities in South Africa. The knowledge section of the questionnaire included content (CK) and pedagogical content knowledge (PCK). Pre-service science teachers' belief bundles were divided into five categories which were beliefs about (i) the nature of science (BLF1), (ii) learning science (BLF2), (iii) science achievement (BLF3), (iv) preparedness for teaching physical science (BLF4) and (v) programme effectiveness (BLF5). OTL that were considered included OTL tertiary-level physics and chemistry (OTL1), OTL school-level physical science (OTL2), OTL science education/pedagogy (OTL6), OTL through reflection (OTL9), OTL through teaching practice (OTL11, OTL12 and OTL14) and OTL in a coherent programme

(OTL15). The self-administered questionnaire was validated using various methods including Cronbach alpha's ($\alpha > 0.66$) and the knowledge section was validated using Rasch analysis (reliability indices > 0.66). ANOVA tests, correlations and stepwise regression analysis were used to determine relationships between OTL and pre-service science teachers' knowledge and beliefs.

The findings suggest that there are significant differences in the knowledge, belief bundles and OTL mean scores of the four universities ($p < 0.05$). Analysis of the data suggests that the universities mean scores on beliefs and knowledge increase with increasing OTL scores although this link is not clear in some cases. Additionally, the mean scores of two universities lend empirical support to the notion that beliefs act as a filter when PST's acquire and construct their knowledge. OTL that address similarities between the methodologies and strategies used by PSTs at schools and the knowledge they are exposed to at the university are predictors of knowledge (CK: $\beta = 0.497$, $p = 0.00$) and beliefs variables (BLF1: $\beta = 0.319$, $p = 0.000$; BLF2: $\beta = 0.265$, $p = 0.013$; BLF3: $\beta = 0.184$, $p = 0.049$). Similarly, OTL that address similarities between the methodologies used by mentor teachers at school and the knowledge that PSTs are exposed to at the university show some effects with multiple knowledge (PCK: $\beta = 0.230$, $p = 0.005$) and beliefs variables (BLF1: $\beta = 0.432$, $p = 0.000$; BLF2: $\beta = 0.176$, $p = 0.099$; BLF3: $\beta = 0.319$, $p = 0.001$). OTL that address links between courses offered to PSTs including sequencing of and links between courses offered in teacher education programmes also explain the variance observed in the mean scores of knowledge (CK: $\beta = -0.264$, $p = 0.001$) and beliefs variables (BLF3: $\beta = -0.214$, $p = 0.004$; BLF4: $\beta 1 = 0.313$, $p = 0.000$; BLF5: $\beta 2 = 0.199$, $p = 0.005$). OTL tertiary level physics and chemistry is also a predictor of multiple knowledge (CK: $\beta = 0.321$, $p = 0.001$; PCK: $\beta = 0.219$, $p = 0.023$), and beliefs variables (BLF1: $\beta = 0.192$, $p = 0.001$; BLF2: $\beta = 0.269$, $p = 0.000$; BLF3; $\beta = 0.159$, $p = 0.019$; BLF4: $\beta = 0.118$, $p = 0.030$). The findings recommend that teacher education programmes could be based on the principle of *coherence* because of the possible positive effects on aspects of PSTs competence. The study therefore proposes that the design of teacher education programmes

could be based on the OTL mentioned and they could also be emphasised in already existing teacher education programmes.

Key words: Science teacher education, pre-service science teachers, science teacher beliefs, teacher knowledge, competence, opportunities to learn.

Acronyms

ANOVA – Analysis of Variance

BEd – Bachelors of Education

CDE – Centre for Development Enterprise

CK – Content Knowledge

DBE – Department of Basic Education

DoE – Department of Education

FET – Further Education and Training

GPK – General Pedagogical Knowledge

HOD – Head of Department

IEA – International Association for the Evaluation of Educational Achievement

IMPPACT – Investigating the Meaningfulness of Preservice Programs Across the Continuum of Teaching

MCAR – Missing Completely at Random

MRTEQ – Minimum Requirement for Teacher Education Qualification

NQF – National Qualifications Framework

OTL – Opportunities to Learn / Opportunity to Learn

PCK – Pedagogical Content Knowledge

PIRLS – Progress in International Reading and Literacy Study

PISA – Programme for International Student Assessment

SPSS – Statistical Package for Social Sciences

PSTs – Pre-service Teachers

TEDS-M – Teacher Education and Development Study: Learning to Teach Mathematics

TEIs – Teacher Education Institutions

TIMSS – Trends in International Mathematics and Science Study

Chapter 1

Introduction to the research study

1.1 Introduction and background

Literature suggests that the quality of a school system depends on the quality of teachers in the system (Adombent & Hoffman, 2013). As such, numerous investigations have focused on issues concerning teacher quality, including the quality of science teachers (Bolyard & Moyer-Packenham, 2008; Hollins, 2011). Quality teachers are those that display competence and exceptional skills in teaching and learning situations (Bolyard & Moyer-Packenham, 2008). Current trends in science education indicate that the roles that teachers play are changing and expectations about them are changing as well. For example, science teachers, similar to teachers of other learning areas, are now expected to integrate learners with special needs into mainstream classroom, teach multicultural classrooms and use information and communications technologies (ICTs) effectively in their classrooms (OECD, 2011). It is therefore essential to have teachers who are sufficiently trained to deal with the ever-changing landscape of education today. Indeed, quality teaching is regarded as a central aspect towards the realisation of the South African development agenda (Moon, 2007).

To teach effectively, teachers need to understand learners' level of science knowledge and the gaps in their knowledge in order to support them adequately in their learning. Learners are expected to master basic skills and concepts in science for continued success in future science grades and/or courses (Duschl, Schweingruber & Shouse, 2007). The implication is that teachers should be knowledgeable enough to help learners construct knowledge in a learning area such as physical science.

In addition to knowledge, teachers' instructional practices are also influenced by their beliefs regarding a subject (Tondeur, Van Braak, Ertmer & Ottenbreit-Leftwich, 2016). Although inquiry-based approaches require teachers to possess in-depth knowledge of content and pedagogy, factors such as context, beliefs and curriculum also influence the way teachers present the subject content in classrooms (Blomeke & Kaiser, 2014; Magno, 2011). Keys and Bryan (2001:231) argue that

> The proposal of a research agenda for inquiry approaches that are centred on teacher beliefs and knowledge may accelerate the production of a research literature that bridges the important theory-practice gap in this important area.

For pre-service teachers (PSTs), the development of the competence to teach, which includes knowledge and beliefs, occurs in their initial teacher education programmes. The realisation is that teacher education institutions (TEIs) have the responsibility of training and producing quality and competent teachers (Kazempour & Sadler, 2015). There is also evidence that suggests that in-service teacher training has had little impact on schooling, which in turn suggests that the greatest opportunity to improve the quality of schooling rests with improving initial teacher education programmes (Taylor, 2014). TEIs should therefore be organised in such a way that PSTs are able to attain quality experiences regarding teaching and learning. In other words, TEIs should afford PSTs sufficient opportunities to learn (OTL) about the actual work they will perform to ensure that they graduate as competent novice teachers. The study of teacher education programmes may in this instance provide further understanding of the conditions in teacher education programmes that lead to competent teachers (Blomeke & Kaizer, 2014).

The term ‘opportunities to learn or opportunity to learn’ refers to numerous situations of learning in initial teacher training that PSTs are exposed to. OTL may be in terms of content exposure, content coverage, quality of instructional delivery, content emphasis and exposure to practical teaching, to mention but a few (Blomeke & Kaizer, 2014). Although there is evidence that OTL is related to educational outcomes, structural features such as programme or degree type do not show a significant relationship to teaching outcomes like learner achievement and teacher competence (Goldhaber & Liddle, 2011). On the contrary, the quality of educational programmes seems to influence teaching and learning outcomes significantly (Boyd, Grossman, Lankford, Loeb & Wyckoff, 2008). This suggests that if PSTs are exposed to quality OTL, they may become quality science teachers in the future.

In the past, South Africa participated in international comparative studies such as Progress in International Reading and Literacy Study (PIRLS) and Trends in International Mathematics and Science Study (TIMSS). The variations in learners' achievement recorded in these studies, like in other countries, have prompted researchers to investigate the origins of such variations. The variations ultimately prompted considerable interest in teacher competence amongst other variables and its effects on learner achievement (Blomeke *et al.,* 2012). Blomeke and Kaiser (2014) explain that tests such as PIRLS and TIMSS provide a benchmark for teacher education institutions and systems in that the countries that perform well are regarded as having effective teacher education programmes than those that do not perform well. This interest led to the development of Teacher Education and Development Study: Learning to Teach Mathematics (TEDS-M), whose goal was to assess PSTs' competencies in teaching mathematics (Blomeke *et al.,* 2012; Blomeke & Kaiser, 2014). Comparative studies such as TEDS-M afford the opportunity to study the implicit character of various education programmes and consequently, the differences in various countries scores provide ideas about what constitutes effective teacher education programmes. The TEDS-M study advanced our knowledge on several key issues regarding pre-service mathematics teachers training, but there is a need to extend the generation of knowledge to other critical learning areas as well.

The need to understand how teachers and specifically, effective science teachers are prepared is evident in the literature. A number of scholars from various countries including South America (Cofré *et al.*, 2015), China (Liu, Liu & Wang, 2015), Europe (Evagorou, Dillon, Viiri & Albe, 2015), North American countries (Olson, Tippett, Ohana & Clough, 2015) and Africa (Ogunniyi & Rollnick, 2015) have summarised initial teacher preparation programmes in their part of the world. The summaries focus mainly on the manner in which science teachers are recruited, prepared, mentored and supported with the goal of providing a more comprehensive picture on issues concerning science teacher education from different perspectives. This shift in the research agenda from determining elements of initial science teacher preparation addresses Wilson's (2011) frustrations about science teacher education literature. Wilson argues that there is sufficient literature on science teacher education and what is needed is the determination of elements of science teacher education that lead to effective programmes i.e. elements of science teacher education that significantly predict PSTs skills, knowledge and beliefs. The summaries from the various countries suggest that there is growing interest in the complexities and intricate details of science teacher education, including PSTs' experiences of teacher education programmes.

1.2 Problem statement

Conventional logic suggests that teacher education affects PSTs' attributes and competence but there is still a need to understand the manner in which teacher education contributes to teacher competencies (Blomeke, Suhl, Kaiser & Dohrmann, 2012; Boyd *et al.*, 2008). Although teachers have been trained at TEIs for decades, the effects of the experiences PSTs are exposed to on their knowledge, beliefs and classroom practices have not been investigated adequately (Darling-Hammond *et al.*, 2009; NRC, 2010; Wilson, Floden & Ferrini-Mundy, 2001). Tobias (2010) explains that the failure of teacher educators in designing mechanisms that ascertain the effectiveness of teacher education programmes in preparing highly qualified teachers has opened the field to widespread criticism.

Indeed, very little is known about the intricacies of initial teacher education; therefore, it is now the time to investigate the effects of teacher education programmes on PSTs in order to advance our understanding of how teacher education contributes to teacher competence (Adler *et al.,* 2009; Boyd *et al*., 2008). There are also concerns that there is not much in terms of research on how teacher education contributes to teacher professional knowledge and beliefs (Bryan & Atwater, 2002; Richter *et al*., 2010). While knowledge on instructional opportunities that are valuable for teachers has increased, the body of knowledge is largely descriptive and there is a lack of investigation into the relationships between specific aspects of teacher education and teacher education outcomes (NRC, 2010). The lack of research into these issues suggests that pre-service science teacher education programmes have little or no empirical grounding and more should be done to understand the development of science teachers at various stages of their careers (Luft, Roehrig & Patterson, 2003; Zeichner, 2005).

Researchers have investigated the link between teacher competencies and teacher education in the literature (e.g. Cochran-Smith & Zeichner, 2005; Tollitson & Young, 2013; Yager & Apple, 1993). However, these studies focus mainly on assessing teacher beliefs and studies that involve direct measurement of PSTs knowledge are still limited (Brouwer, 2010). Some studies have investigated the relationships between OTL, knowledge and beliefs in science education (Ingvarson, Beavis & Kleinhenz, 2007; Tillotson & Young, 2013) but studies that holistically determine the effects of OTL on PSTs knowledge and beliefs are rare. More than assessing OTL that significantly affect PSTs knowledge and beliefs, there are even fewer studies that determine and identify OTL that are predictors of multiple aspects of PSTs' competence. The present study's investigation is centred around OTL that predict multiple beliefs and knowledge variables because these OTL may provide aspects of science teacher preparation that give the greatest purchase in terms of PSTs learning.

1.3 Research questions

The current study sought to determine the OTL in teacher education programmes that are significant predictors of pre-service teachers' knowledge and beliefs in South African TEIs. To achieve this, the study attempted to answer the following research questions.

1. What is the level of knowledge of pre-service physical science teachers in some South African universities?
2. What are PSTs' beliefs about teaching and learning of physical science?

3. What kinds of OTL are pre-service science teachers exposed to in some South African universities?
4. What are the relationships between PSTs' knowledge, beliefs and the OTL they are exposed to?
5. Which OTL are significant predictors of multiple variables in the knowledge and beliefs constructs?

1.4 Aims of the study

The study sought to

1. Determine PSTs' levels of knowledge regarding the teaching and learning of physical science.
2. Evaluate PSTs' beliefs with regard to teaching and learning of physical science.
3. Assess the kinds of OTL that physical science PSTs are exposed to in some South Africa universities.
4. Determine OTL that are significant predictors of pre-service physical science teachers' beliefs and knowledge.
5. Assess the OTL that are predictors of more than one variable in the knowledge and beliefs construct.

1.5 Conceptual considerations

The challenges in education are complex and cannot be attributed to a handful of factors (Ingersoll, 1999). Although this is the case, the consensus is that there is a need for effective and competent teachers in classrooms (Darling-Hammond & Richardson, 2009; Desimone, 2011; Hollins, 2011). Competence is defined as a combination of knowledge, willingness and ability to cope with the changing situation successfully and in a responsible manner (Weinert, 2001). The European Commission (2013) holds a similar view of competence. They describe it as a complex combination of attitudes, skills, knowledge and values that allow for appropriate action to be taken in situations. The present study views competence as a function of knowledge and beliefs. This definition is somewhat similar to Leisens' (2009) as cited in Adomßent and Hoffmann (2013) definition, which states that competence is the active handling of knowledge. The present study therefore views competence as an active handling of knowledge underpinned by a desirable set of beliefs. I do acknowledge that practical competencies in this context are important. However, the resources required to assess the said competencies for a moderately large number of respondents from different universities reliably are sizeable and therefore only two aspects of competence (knowledge and beliefs) are investigated.

OTL has been used extensively in international comparative studies, at least for explaining the achievement gaps in the teaching and learning of mathematics and science (Floden, 2002). More often than not, there have been numerous positive associations between OTL in schools and learner achievement in literature, giving rise to extensive research on the relationship between learner achievement and schooling. The present study follows this line of thinking and it investigates relationships between elements of teacher education programmes and aspects of PSTs' competence in terms of their beliefs and knowledge.

In terms of OTL, this study investigates the implemented curriculum in teacher education programmes, including the overall OTL afforded by the curriculum. This includes variables such as content taught and its organisation, the enacted curriculum and standards, institutional opportunities including field based experiences. The study further investigates the achieved outcomes of teacher education. This includes PSTs' acquired content knowledge, knowledge of teaching science and their belief bundles.

The conceptual framework will be discussed thoroughly in Chapter 2.

1.6 Methodological considerations

This study employed a quantitative approach, because quantitative analysis allowed for measurement and for statistical treatment of the data (Johnson & Christen, 2012). The approach further allowed for the assessment of the statistical relationships that could exist between PSTs' knowledge, beliefs and the OTL that PSTs are exposed to. Non-experimental designs in the form of surveys and an achievement test were used to collect data. The use of surveys allowed for the collection of information such as opinions, attitudes and beliefs of respondents and to compare or relate the data to a specific variable (Creswell, 2014).

I invited all institutions (traditional, comprehensive universities and universities of technology) that offer undergraduate teacher education qualifications to participate in the study. At the end, only four universities agreed to participate, with 112 respondents. The respondents were pre-service physical science teachers who were in their final year of study. This was done with the understanding that they would have developed most of the necessary competencies for teaching at that point.

Teacher knowledge was assessed by means of an achievement test, which comprised items that measure pre-service science teachers' pedagogical content and content knowledge.

Teacher beliefs were measured by means of a survey. The belief bundles that were surveyed include beliefs about (i) the nature of science; (ii) learning science; (iii) science achievement; (iv) preparedness for teaching physical science; and (v) programme effectiveness.

The survey for OTL measured OTL tertiary-level physics and chemistry, OTL school-level physical science, OTL physical science education/pedagogy, OTL teaching through reflection on practice, OTL through teaching practice and OTL in a coherent teacher education programme.

Data were collected in the first semester of 2017 when the PSTs were almost at the end of their training. I personally administered the questionnaire in all the institutions with the aid of a research assistant at two of the universities.

The collected data were subjected to validity and reliability tests such as Cronbach's alpha test to determine the internal and external consistency of the survey items, and Rasch analysis for the achievement test to determine the tests ability to discriminate between respondents (McMillan & Schumacher, 2014). Mean scores of the variables were calculated and all the other scores from various institutions were compared with the aggregated score. The OTL data were compared and used to understand teacher knowledge and beliefs data.

Data were subjected to inferential statistics to determine if there were any statistically significant relationships among the measured variables. Analysis of variance (ANOVA) was used to assess the differences between the four universities' data. The constructs (teacher knowledge, beliefs and OTL) were correlated to determine the extent to which they relate to each other. Regression analysis was performed to determine significant OTL predictors for the dependent variables. The variables were assigned codes to simplify data analysis and the data were reported by means of tables and interpreted accordingly.

The methodology will be discussed thoroughly in Chapter 3.

1.7 Purpose of the study

International comparative assessments such as the TIMSS and Programme for International Student Assessment (PISA) have shown that South African learners lag behind many countries in terms of achievement in science (HSRC, 2011). While there may be numerous reasons for this, literature suggests that teacher knowledge and beliefs may also be some of the contributing factors (Tatto *et al.*, 2012; Tillotson & Young, 2013). Many resources are currently used to improve the knowledge of teachers in the country through various projects (Adler *et al.*, 2009). All this indicate that there are concerns about the levels of mathematics and science teacher knowledge in the country. Furthermore, various studies have shown that professional preparation is important especially in equipping teachers to teach learners with different learning styles and cultural backgrounds (Constantine *et al.*, 2009). There is therefore a need to understand the influence of the structure of teacher education programmes on aspects of teacher competence. This study therefore attempts to discern aspects of teacher education that are indicative of effective programmes.

Science has been and still is at the forefront of numerous technological advances and it is imperative that today's science teachers understand and appreciate the processes of science. In order to achieve this appreciation for science, the type of experiences that science teachers are exposed to at teacher education institutions should be investigated. This may ultimately assist in the designing of programmes that will produce competent teachers, which in turn may improve learner understanding of science concepts. The present study's main aim is to identify elements of teacher preparation that may have a significant impact on aspects of PSTs' competence, as this will inform policy and practice in terms of best practices for science teacher education.

Although teacher education programmes in South Africa use the same framework, there will likely be differences in the implementation of the framework because of historical and cultural differences between various institutions as shown by Taylor (2014). The present study therefore compares the beliefs, OTL and test performance of the respondents from the four universities. This allows for the portrayal of similarities and differences in OTL that may influence pre-service teachers' test performance and beliefs. The comparisons also allow for the determination of the kinds of OTL that may likely lead to science teachers with adequate knowledge and desirable beliefs. Furthermore, teachers are prepared at what is known in South Africa as traditional universities and universities of technology. Universities of technology evolved from what was known as technikons and what separated them from traditional universities was that the technikons' curricula were designed to expose students to practical aspects of the work place more than traditional universities (Council on Higher Education, 2010). The expectation is that teachers from universities of technology are exposed to more relevant OTL than traditional universities and this study will reveal more in that regard. Whether this, if found to be true, will have an effect on PSTs' competence is an open question at this stage.

A fair number of studies have investigated pre-service science teachers' knowledge and beliefs but very little work has been done to link the two with the OTL that PSTs are afforded. There are international studies that have linked primary and lower secondary mathematics PSTs' competence and OTL (Schmidt, Cogan & Houang, 2011; Tatto *et al.*, 2012). Although mathematics and science are usually placed in the same category, the methodologies used in the teaching of either subject somewhat differ. Consequently, the OTL that the two sets of PSTs are exposed to are likely to differ as well. This study assesses the OTL that will likely lead to graduate science teachers with adequate knowledge regarding teaching and learning. Moreover, the international comparative studies did not include South African TEIs; therefore, this study explores the OTL that pre-service physical science teachers are exposed to in the context of South African TEIs. This study also focuses on PSTs in the further education and training (FET) band (i.e. Grades 10-12).

In simple terms, the present study's main aim is to determine OTL that predict multiple knowledge and beliefs variables and to provide a set of OTL that policy makers and teacher educators could base the design of their programmes on. This set of OTL could also be used in reconfiguring and improving current teacher education programmes.

1.8 Significance of the study

This study assists researchers in understanding the kinds of OTL that pre-service teachers are exposed to at South African teacher education institutions. It is important to understand these because the knowledge generated will provide the education community with information regarding the type of science teacher the TEIs are training and producing. The study examines various kinds of OTL pre-service science teachers are exposed to in various TEIs and the manner in which the OTL affect aspects of PSTs' competence.

Teacher education is complex and there is much disagreement amongst experts, policy makers and researchers about the kind of knowledge that is important for teaching purposes. There are competing views on the importance of pedagogy, reflection and content knowledge (Ucar & Sanalan, 2011). Furthermore, there are disagreements on issues such as the type of knowledge PSTs acquire from practical experiences, the relationships between theory and practice, and the impact of prior knowledge on teacher learning (Tatto, 2007). This study attempts to provide clarity on some of these disagreements.

The study contributes to the literature by determining if there are any associations between the OTL that pre-service physical science teachers are exposed to, and their beliefs and knowledge. This helps in determining the OTL that may lead to the training of competent physical science teachers. Tobias (2010) contends that the comprehension of these connections may be used as a lens to guide the current practices and as a feedback mechanism to assess and improve existing teacher education programmes.

1.9 Definition of key terms

Opportunities to learn:

Wallace (2009) conceptualises OTL as events or activities that enable the learner to acquire the expected skills and knowledge. Floden (2002) summarises the different conceptualisations of OTL in terms of what other researchers have measured. He explains that OTL can be measured by assessing the extent to which a topic is mentioned or emphasised in the national, state, district and school curriculum.

Teacher knowledge:

Shulman (1986, 1987) provides valuable insights into teacher knowledge and his ideas regarding teacher knowledge have been used extensively in numerous learning areas. Teacher knowledge for content specific domains has traditionally been subdivided in dimensions which include pedagogical content knowledge (PCK), content knowledge (CK), curricular knowledge and general pedagogical knowledge (GPK) just to mention a few (Shulman, 1986).

Teacher beliefs:

Beliefs are defined in the current study, according to Richardson's (1996:103) definition as "understandings, premises or propositions about the world that are felt to be true". The current study focuses on PSTs' beliefs regarding teaching and learning of science and general aspects of teacher education in the context of physical science.

Teacher competence:

The European Commission (2013) describes teacher competence as complex combinations of skills, knowledge, values, attitudes and understandings which allow for appropriate action to be taken in situations. Teacher competence can therefore be understood as a dynamic interplay of cognitive and meta-cognitive skills (González & Wagenaar, 2005) and it consists of four basic aspects, which are learning to *know*, *think*, *act* and *feel* as teachers (Feiman-Nemser, 2008).

1.10 Outline of the Chapters

Chapter 1

This chapter introduces the study. It contains the problem statement, research questions and the aims of the study. The purpose of the study and its significance are addressed in this chapter as well.

Chapter 2

This chapter covers the framework of the study and the relevant literature. The chapter considers literature concerning teacher knowledge, beliefs and OTL with the perspective of science teacher competence.

Chapter 3

This chapter discusses methodological considerations of the study. It describes how data was collected and it describes the process of selecting the respondents for the study including data analysis.

Chapter 4

The chapter presents the findings of the study. All the tables, statistical calculations and tests are presented in this chapter. The discussions of the findings are also presented in this chapter.

Chapter 5

The chapter provides an overview of the study followed by summary of the key findings. Conclusion of the study including recommendations and limitations of the study are presented in this chapter.

Chapter 2

Conceptual framework and review of literature

I never teach my pupils; I only attempt to provide the conditions in which they can learn.

- Albert Einstein

2.1 Introduction

This chapter provides an overview of the concept of competence and its definition. It begins by operationalising competence as a function of two constructs, namely knowledge and beliefs, after which recent studies on the constructs are briefly reviewed. The chapter proceeds to introduce the 'opportunities to learn' concept and its development to recent conceptualisations. The chapter concludes by reviewing links regarding the effects of opportunities to learn on aspects of teacher competence, i.e. teachers' knowledge and beliefs from the literature.

2.2 The concept of competence

The challenges concerning education are complex and they cannot be attributed to a single or a handful of factors. Although this is so, one factor that most researchers agree on is that there is a need for quality teachers in schools (Goe, 2007; Goe, Bell & Little, 2008; Rothstein, 2010). A key objective for every education system is to ensure that all the children are taught by qualified and competent teachers (Kind, 2014). This is in line with the vision of the Centre for Development and Enterprise (CDE, 2013) that, by improving the quality of education and especially teacher quality and competence in South Africa, the country will be able to support economic development and lessen inequalities.

The concept of competence was used in an attempt to find a compromise between two points of view. At that time, educational science scholars in Germany had disagreements regarding the outcomes of training/education in a society. One group believed in the development of personality and allowing participation in the human culture, while the other group advocated the development of vocational knowledge and skills necessary for practice (Klieme, Hartig & Rauch, 2008). The introduction of competence was a shift from a traditional view (the two views expressed above) of education to an emancipatory view and it provided the two groups with a more inclusive point of view. Competence as conceptualised then was very broad and it was difficult to develop instruments that measure competence, partly because there was no functional definition for the concept. Nevertheless, some scholars have recently offered definitions for the concept.

Competence is defined as a combination of knowledge, willingness and the ability to cope responsibly and successfully with the changing situation (Weinert, 2001). Competence is therefore regarded as a set of activities or inherent qualities that allow professionals to do their job effectively, i.e. to master job-related tasks (Weinert, 2001). On the other hand, Simonton (2003: 230) regards competence as "any acquired skill or knowledge that constitutes an essential component for performance or achievement in a given domain". Similar to Simonton, Katane and Selvi (2006) define competence as a set of knowledge, skills and values necessary to create and foster meaningful experiences when organising an activity. While the two definitions are in many ways like the others, Katane and Selvi's (2006) definition adds 'values' to the dimensions of competence. The European Commission (2013) holds a similar view of competence and it describes it as a complex combination of skills, knowledge, values and attitudes, which allow appropriate action to be taken in situations. An individual's values, attitudes, confidence, self-esteem and self-concept are included in their beliefs (Hancock & Gallard, 2004) and, as such, competence has to do with an individual's beliefs. In the present study's view, competence can be expressed as

$$\text{Competence} = \text{knowledge} + \text{beliefs} + \text{skills} = \text{desirable action}$$

The present study therefore views competence as an active *handling of knowledge* and this handling of knowledge is underpinned by a desirable set of beliefs.

It is necessary to define teacher competence in a flexible manner as suggested by Naumescu (2008), because it can then be applied to professionals at various stages of their careers, depending on what is expected of them at that stage. This view is useful to the current study, because it allows for the development of a competence framework for novice teachers. This means that specific aspects of what teachers should be competent in at the end of their training can be developed and used to judge if they are ready to embark on a teaching career.

The present study will only focus on knowledge and beliefs as aspects of PSTs' competence. The reason for this choice is explained in the sections that follow.

2.2.1 Aspects of teacher competence

Teacher competence is a dynamic interplay of cognitive and meta-cognitive skills (González & Wagenaar, 2005). It consists of four basic aspects, namely learning to *know*, *think*, *act* and *feel* as teachers (Feiman-Nemser, 2008).

Learning to know as teachers refers to the knowledge required for teaching including practice-based knowledge. Teacher competence is based on good frameworks of knowledge with the support of metacognitive skills and good management strategies for retrieval and use of the knowledge (Feiman-Nemser, 2008). Sound knowledge of a subject as well as the ability to convey the knowledge is required and it should be supported by the knowledge of how to support learning through the use ICTs as we live in the digital era (Groff & Mouza, 2008). Epistemological knowledge such as the history, structure and culture of the subject is also necessary. Other types of essential knowledge include knowledge of class management, school curricular, education theories, methodologies and assessment. All these types of knowledge should be used to influence wider educational aims positively (Darling-Hammond & Bransford, 2005).

Learning to think as teachers has to do with being critical of one's beliefs and the development of pedagogical thinking, which links to the aims and objectives of the teaching and learning process. Among others, learning to think as teachers involves developing meta-cognitive awareness as well. Teachers should therefore develop decision and thinking skills in teaching, reflection skills and the ability to adapt practices (Hay-McBer, 2000).

Learning to act as teachers involves integrating knowledge and thoughts in practice, which are underpinned by consistent principles. Teachers' actions in the classroom should always be informed by effective teaching principles and while this is so, the classroom can be an unpredictable place. Too often, teachers' intentions and actions do not match (Hajer & Noren, 2017; Kennedy, 1999; O'Donnel, 2008). The act of teaching requires teachers to possess and use a range of skills, strategies and action patterns effectively. Therefore, a teacher needs to be able to judge a situation and act accordingly i.e. a teacher needs to have adaptive skills (Hagger & McIntyre, 2006).

Learning to feel as teachers comprises the professional identity of the teacher, which includes some emotional and intellectual aspects (Hagger & McIntyre, 2006). According to the European Commission (2013), learning to feel as teachers includes leadership (passion for learning, accountability and flexibility), expectations (information seeking, drive for improvement and initiative) and attitudes (respect, confidence, commitment and trustworthiness). It also involves aspects of self-awareness, self-efficacy and mediation between aims, ideals and school realities (Geijsel, Sleegers, Stoel & Krüger, 2009). Teachers are also expected to have the correct attitude or beliefs to guide their action in an effort to maximise the learning potential of every learner (Feiman-Nemser, 2008).

The aspects of teachers' competence mentioned have been summarised in many countries as the well-known competencies of a teacher. A teacher is regarded as a knowledgeable expert, a reflective agent, social agent, classroom actor and a lifelong learner just to mention a few. These competencies provide a useful framework that can be used to spark dialogue aimed at conversations on how to prepare effective teachers in an education system best. The whole spectrum of teacher competencies is summed up in Figure 2.1, which displays the multi-level and multi-faceted nature of teacher competence. The present study recognises the importance of the aspects of teacher competence as captured in Figure 2.1 and some of the aspects were considered in the development of the instruments used in the study.

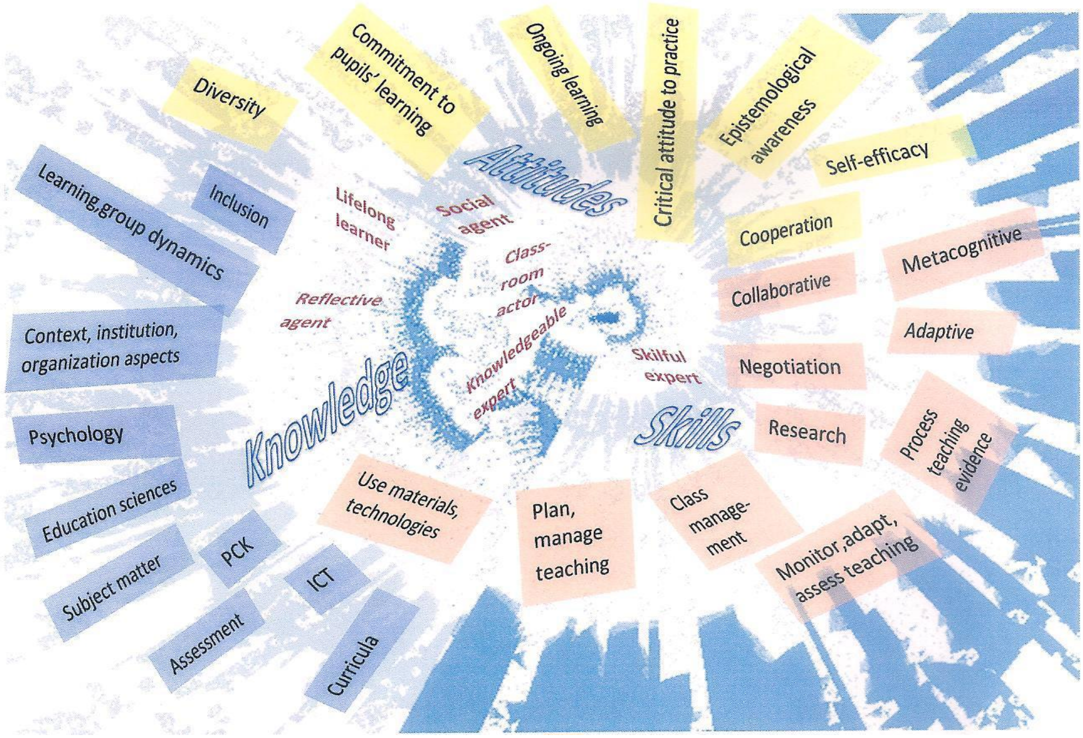


Figure 2.1: Teacher competencies, a fractal view (Caena & Margiotta, 2008)

2.2.2 The need to define teacher competencies

There are numerous reasons why there is a need to define the competencies teachers should possess at different stages of their careers in an education system. In most cases, the desire to define teacher competencies is driven by results from large-scale international tests where a country may wish to explore the underlying reason for their performance (Schmidt *et al.*, 2008; Zhao, 2010). At times, it may be because of the need to improve the effectiveness of an education system or it may be for reform purposes where policy makers describe the kind of teachers they wish to have in classrooms (Fraser, Killen & Nieman, 2005a).

For the teaching profession itself, the need to define the competencies may be for attempts to make the teaching profession more attractive and for progression purposes (Adomßent & Hoffmann, 2013). The idea of competence also assists in the professionalisation of teaching and clarifying the roles a teacher is expected to undertake. Teacher competence also plays a pivotal role in the assessment of qualities of a teacher and it assists in efforts to sensitise teachers towards pursuing lifelong learning and professional development (Fraser, Killen & Nieman, 2005b).

Frameworks associated with teacher competence have been used in numerous countries (e.g. the US, UK, Japan, etc.) to grant and withdraw teaching licences and to monitor teacher performance and professional development (Boyd, Goldhaber, Lankford & Wycko, 2007). Aspects of competence have also been used as a benchmark for teachers who are on probation and for designing initial teacher preparation programmes (Angrist & Guryan, 2008). If the frameworks for teacher competence are planned and developed appropriately, they may have numerous benefits for an education system.

2.2.3 Competence and assessment

Weinert (2001) suggests a concept of competence that should be used in large-scale studies. He defines it as a set of tasks and situations that should be mastered. He further explains that learners or teachers should be confronted with these tasks and situations during their assessment because this type of assessment is more reliable than just assessing knowledge. Although task- and situation-oriented assessments are more desirable, they tend not to be practical because of the resources required to conduct such assessments (Klieme *et al.*, 2008). The present study is also of the view the observing a fairly large sample PSTs will require substantial time, human and financial resources. Organisations have commissioned large-scale studies such as PISA, TIMSS and TEDS-M with the specific aim of measuring teachers and learners' competencies (Schmidt, Wang & McKnight, 2005). The frameworks employed by large-scale studies focus on teacher professional knowledge and other attributes such as teacher beliefs, attitudes etc. The current study therefore adopts the large-scale studies positions and it uses surveys (beliefs) and achievement tests for the assessment of competence.

In summary, teacher learning begins at teacher education institutions. It carries on during their induction and continues throughout the rest of their careers (Wilson, 2011). This suggests that not only one process or type of knowledge results in a competent teacher, but the culmination of all knowledge and experiences may result in a quality and competent teacher (Fraser *et al.*, 2005a; Fraser *et al*., 2005b). As the stages one goes through to become a competent teacher are vast and complex, the current study will only focus on the competence of teachers at the pre-service stage. The current study views competence as a function of knowledge and beliefs, which is a view similar to other large-scale studies that assess competence. The two constructs, i.e. knowledge and beliefs are discussed in the next section.

2.3 Teacher knowledge

Over the past 20 years, education reforms and teacher professional development interventions have focused more on teacher knowledge in efforts to improve teaching and learning in schools. Scholars recognise that teachers themselves, combined with their knowledge and beliefs are a crucial part of educational reform (Avraamidou & Zembal-Saul, 2010; Park & Oliver, 2008). As a result, numerous professional development interventions have focused on improving teacher knowledge, skills and values (Darling-Hammond & Richardson, 2009; Desimone, 2009; Guskey & Yoon, 2009). Teacher knowledge can be defined as the total knowledge at the teacher’s disposal (Ben-Peretz, 2011). The origins of teacher knowledge range from practical experiences such as day-to-day teaching in the classroom and professional development interventions to initial teacher education experiences (Verloop, Van Driel & Meijer, 2001).

Shulman (1986, 1987) provides valuable insights into teacher knowledge and his framework for teacher knowledge has been used extensively in numerous learning areas (e.g. Ball, Thames & Phelps, 2008; De Jong, Van Driel & Verloop, 2005; Mavhunga & Rollnick, 2013). Shulman argues that teacher knowledge for content-specific domains can be subdivided into categories, which include content knowledge (CK), pedagogical content knowledge (PCK), general pedagogical knowledge (GPK), curricular knowledge and knowledge of learners, to mention a few (Shulman, 1986). This knowledge is understood to be what a teacher partly draws on when taking actions in a particular situation such as a classroom. Of all the categories suggested by Shulman (1986; 1987), scholars have shown great interest in investigating aspects pertaining to CK and PCK, probably because they are considered to be the categories closely related to the cognitive attributes of a teacher (Park & Oliver, 2008). The present study also measures two categories of teachers' knowledge, namely PCK and CK.

2.3.1 Complexities of teacher knowledge

Pre-service teachers need to be exposed to sufficient knowledge for them to be effective teachers but the contents of that knowledge tends to be a contentious issue. As the National Research Council (NRC, 2010) notes, there seems to be two competing views with regard to the ideal preparation of teachers. One school of thought suggests that one should only be well educated in the content area of interest to be a good teacher and that teacher education is not necessarily important. The other school of thought suggests that teachers need widespread preparation experiences that focus on the teaching and learning of a content area (Santau, Maerten-Rivera, Bovis & Orend, 2014; Schmidt *et al.*, 2011). Simply put, the first school of thought suggests that a teacher needs to master only the content they teach, while the second one suggests that pedagogy is important and should be the one that is emphasised in teacher preparation.

The type of content knowledge needed by PSTs has also been in the spotlight over the past few years. There are disagreements on the amount and type of content knowledge that PSTs should be exposed to (Adler *et al.*, 2009; Shwartz *et al*., 2009). The common assumption is that if a teacher has studied a content area to a degree level, then the teacher should be able to teach the content at school level effectively. On the other hand, there is a belief that teachers should be exposed more to the type of content they will be expected to teach in schools. The solution to the disagreements in this instance is to determine and explore the type of knowledge that will assist teachers in planning and presenting effective lessons. Ball (2000: 244) captures this debate and notes:

> Three problems stand out; problems that we must solve if we are to meet this challenge to prepare teachers who not only know content, but can make use of it to help all learners learn. The first problem concerns identifying the content knowledge that matters for teaching, the second regards understanding how such knowledge needs to be held, and the third centres on what it takes to learn to use such knowledge in practice.

One of the issues is that teacher educators rarely have the time to model good teaching practices to the PSTs for every core topic in the curriculum (Grossman, 2011). The fact is that teaching a science topic to a diverse group of learners requires varying degrees of cognitive demand.

Teacher knowledge has been investigated at lengths and while this is so, there are gaps in the literature which require attention if we are to understand the best ways to prepare quality teachers. Ball and Forzani (2010: 8) conclude that teacher education programmes "lack a reliable system for preparing those who want to teach". The present study investigates only a small part of the complexities stated above.

2.3.2 Teacher knowledge in science

Science, as with any other subject has its own unique facets such as procedures, structures, organisations and ways of generating knowledge. An adequate comprehension of scientific concepts, including the processes with regard to the nature of science and scientific inquiry form the basis of scientific literacy (Bell, Blair, Crawford & Lederman, 2003). Scientific literacy is a necessity for a scientist and science teacher alike. Teachers need scientific literacy to engage with and navigate a science and technologically rich environment they ply their trade in currently (Cetin, Dogan & Kutlucha, 2014). A science classroom should engage in discourse that aims to link the observable phenomena with its cause at the microscopic level. A science teacher must therefore be conversant with all aspects of science and its processes. In most cases, the challenge is to describe the attributes that define a quality and knowledgeable science teacher, because there are numerous descriptions in the literature and they tend to differ to a certain extent (Rockoff, 2004).

Scholars have studied the dimensions of science teacher's knowledge and their relationships to each other extensively (De Jong, 2009; Friedrichsen, Van Driel & Abell, 2011; Park & Oliver, 2008). The studies have been conducted with pre-service (De Jong *et al.*, 2005), novice (Avraamidou & Zembal-Saul, 2010) and experienced teachers (Henze, Van Driel & Verloop, 2008). Some studies have even contrasted and compared pre-service and experienced teacher's knowledge (Geddis, Onslow, Beynon & Oesch, 1993). Furthermore, some of the studies were undertaken from teaching methods classes (Greenwood, 2003) and teaching practice (Castle, Fox & Souder, 2006) perspectives. The following section focuses on science teacher knowledge and its measurement.

2.3.2.1 Pedagogical content knowledge

A fair amount of research has been devoted to the exploration of PCK and how it influences teachers' decision as well as how it influences learner learning and achievement (Boyd *et al.*, 2008). Scholars often assess PCK using tools such as checklists, concept mapping, structured interviews and classroom observations. The tools are normally used to study PCK's impact on learning but the mentioned tools tend to be time consuming in most cases (Loughran, Mulhall & Berry, 2004).

While scholars do know and agree that a construct such as PCK exists, the process of recognising, articulating and measuring it are difficult for a number of reasons. Firstly, PCK does not manifest itself in one experience or lesson; an extended time is needed for it to be evident (Loughran *et al.*, 2000). Secondly, while researchers can observe PCK when a teacher is presenting a lesson, part of this construct is internal and teachers are normally requested to articulate their PCK. The problem with this approach is that science teachers do not use language that makes their PCK explicit; hence, it is difficult to ascertain the level of their PCK (Loughran *et al.*, 2000). In practice, this leads to a situation where teachers share the tricks of the trade without articulating the reason why they believe those tricks are effective in the classroom.

One promising method of assessing teachers PCK is to employ the use of Pedagogical and Professional-Experience Repertoires (PaP-eRs) and Content Representations (CoRes) conceptualisations (Loughran, Berry, Mulhall & Woolnough, 2006; Loughran *et al.*, 2004). CoRes and PaP-eRs provide a way of holistically assessing teachers' knowledge because the instruments allow for issues around science content and the way science content is taught to be captured and portrayed. The challenge with this methodology is that it works well for a relatively small sample, but it is impractical for a large sample, because it requires numerous resources, including time to execute. The current study uses multiple-choice items to measure PSTs' PCK and although this may not necessarily be the ideal way to measure the variable, the method is more reasonable with regard to time and financial resources (Cohen, Manion & Morrison, 2007).

Studies have reported that PSTs encounter difficulties in applying various methods and strategies when teaching science. PSTs seem to prefer using traditional instruction and they use methods based on inquiry learning and conceptual change to a lesser extent (Aydin & Çakıroğlu, 2010; Oskay, Erdem & Yılmaz, 2009). In some cases, PSTs tend not to be aware of misconceptions or alternative conceptions that learners may have (Nakiboğlu, Karakoc &

De Jong, 2010). Furthermore, some studies suggest that PSTs do not possess adequate knowledge regarding the curriculum as well as knowledge about evaluation and assessment techniques (Aydin & Boz, 2012).

Bektas (2015) investigated PSTs' PCK in topics involving physics, chemistry and biology. Data were collected using open-ended questions from 33 PSTs and it were analysed using descriptive statistics. The author found that the PSTs were proficient in other aspects of PCK and less proficient in others. For example, Bektas (2015) determined that the PSTs had sufficient knowledge of learners and their misconception but they lacked the knowledge of instructional strategies to correct or alleviate the misconceptions. Most of the PSTs in the study indicated that the use of traditional teaching methods is essential for the correction of learner misconceptions.

In their paper, De Jong *et al* (2005) studied the PCK of 12 pre-service chemistry teachers who participated in a course that aims to assist PSTs in teaching secondary school learners the link between phenomena and corpuscular entities. Data were acquired through transcripts of workshop discussions, answers to written assignments and the participants' reflective lesson reports. Their findings indicated that PSTs were able to describe problems learners encounter in learning corpuscular entities and they acknowledged the role that models could play in enhancing learners' understanding thereof. The study suggests that while the PSTs displayed some PCK, it seemed to be shallow and it lacked sophistication. After the intervention, the authors reported that PSTs' PCK was enhanced and it was more sophisticated.

In another study, Aydeniz and Kirbulut (2014) studied the PCK of 31 PSTs using a praxis tool. Although the qualitative study's intention was to test the ability of the praxis tool in enhancing PSTs' PCK, it nonetheless provides some insights into the initial and final states of the PSTs' PCK. Their findings indicated that PSTs' PCK regarding galvanic cells was underdeveloped and the use of a praxis tool and focusing on collegial reflection assisted in the development of the PSTs' PCK.

Much of the literature on PSTs' PCK follows the trend of the above studies in that they first measure the PSTs' PCK, which is found to be lacking in some manner. The participants then undergo a certain intervention, after which it is determined that their PCK is more sophisticated because of the intervention (e.g. Nilsson & Loughran, 2012). The trend indicates that various teacher education programmes use various methods and strategies, if any, to assist PSTs in developing sophisticated PCK and the present study is poised to measure the PCK of PSTs from different institutions. Although it is not the purpose of the present study to investigate the changes in the sophistication of PCK after various interventions, it is desirable to measure the PCK of PSTs close to the end of their training to assess their readiness to enter the classroom.

As PSTs have not yet spent prolonged amounts of time in the classroom, it is reasonable to assume that their PCK will inherently be less sophisticated than that of experienced teachers (Schneider & Plasman, 2011). One must therefore be careful of the manner in which PCK is assessed so as not to assess components of PSTs' PCK that will develop with more time in the classroom (National Science Teachers Association, 2003). While this argument has proven to be valid, there are minimum standards that a PST must meet to be considered a competent novice teacher in different countries.

2.3.2.2 Content knowledge

Although CK is not the only essential category of knowledge for teachers to have, without it, other types of knowledge fail to support teaching for conceptual change (McConnel *et al.*, 2013). A common assumption is that teachers have sufficient CK and when difficulties in teaching appear, scholars tend to look to other domains of knowledge, potentially disregarding problems that may lie in teachers' CK (Rollnick *et al.*, 2008).

Windschitl (2009: 6) argues that ''teachers with stronger content knowledge are more likely to teach in ways that help learners construct knowledge, pose appropriate questions, suggest alternative explanations, and propose additional inquiries''. Coherent and deep physical science CK is a prerequisite for a teacher to give clear explanations and for the identification of relevant and accurate examples for concepts in a learning area (McConnel *et al.*, 2013). The authors further argue that there is a need for science teachers to understand science concepts adequately in order to organise and implement the curriculum better. This includes teaching using multiple representations and modelling concepts that emphasise the essential details about science concepts (Abd-El-Khalick, 2013). The deep understanding of science also allows teachers to assess learners' understanding and assists them to identify misconceptions (Windschitl, 2009). Insufficient teacher content knowledge may lead to problems in presenting effective science lessons, or as Windschitl (2009: 12) explains,

> Teachers with limited subject matter preparation tend to emphasise memorisation of isolated facts and algorithms; they rely on textbooks without using student understandings as a guide to planning lessons; they use lower-level questioning and rule-constrained classroom activities; furthermore, they employ only limited use of student questions or comments in classroom discourse which results in marginal student development of conceptual connections and misrepresentations of the nature and the structure of the discipline.

In some instances, teachers do not have sufficient understanding of the science content they are expected to teach in schools (Rollnick *et al.*, 2008). Other scholars find that in-service teachers display the same misconceptions as their learners (Aydin, Boz & Boz, 2010). The CK of novice teachers has been described in the literature as piecemeal, less structured and containing inaccuracies (Käpylä, Heikkinen & Asunta, 2009). When PSTs are confronted with content questions, they attempt to provide textbook solutions, which is a sign that they have inadequate conceptual understanding of physical science concepts (Aydin *et al.*, 2010).

Teachers' CK is measured through strategies such as concept mapping and concept inventories, and some researchers have used classroom observation and interviews. Concept mapping involves PSTs drawing structures that represent their understanding of a phenomenon (Govender, 2015; Weizman *et al.*, 2008). However, this type of assessment requires explanations of the diagrams before it can be ascertained if the learner understands the phenomenon properly. Concept maps also require researchers to make numerous assumptions and inferences to support learner ideas and descriptions, which tend to be incomplete (McConnel *et al.*, 2013). Other researchers have used interviews, classroom observations and teacher writings to measure teacher CK in their investigations (Traianou, 2006). The approach is acceptable for eliciting teacher knowledge for small sample sizes. One of the widely used strategies is concept inventories because they are known to be reliable when studying a large sample (Tretter *et al.*, 2007). Concept inventories are useful because they are able to assess if a learner can recognise the correct explanation or descriptions and they permit comparisons amongst different groups of participants (McConnel *et al.*, 2013). Although concept inventories have their inherent weaknesses such as researchers not having insights to learners' thinking, they are nonetheless a reasonable choice for the present study. A detailed account of the development of CK section of the instrument is captured in the methodology section (Chapter 3).

Govender (2015) used a case study to explore PSTs' CK regarding electromagnetism. Data were collected using concept maps and interviews before and after a module on electromagnetism and he tracked the participants CK development as they engaged in individual and collaborative learning. Initially, the concept maps of the participants were linear and had few concepts, linkages and limited propositions. He claims that the participants benefited from the intervention in several ways. The benefits include using new terminology in conceptual linkages, sharing ideas via arguing, explaining to each other and making appropriate conceptual connections supported by experiments.

Bradley and Mosimege (1998) studied PSTs' conceptions regarding acids and bases in a comparative study of teachers who were trained at colleges and universities. While the findings indicate that university-trained teachers were on average more knowledgeable than their college counterparts were, none of the teachers were able to give a proper account of the ions contained in an aqueous solution of hydrochloric acid. Some teachers did not show the water or hydronium ions, drew hydrogen chloride molecules in solution and others suggested that the hydrogen ions are a vapour above the solution.

Similarly, Aksan and Çelikler (2015) used drawings to measure CK and to identify the misconceptions that PSTs may have about greenhouse gases. In total, 327 PSTs were requested to answer questions and to draw sketches as an exhibition of their CK. The results indicated that the PSTs linked the greenhouse effect inaccurately with greenhouses used in agriculture, the thinning of the ozone layer, air pollution, global warming and acid rain. The study showed that most of the PSTs lacked appropriate knowledge regarding greenhouse gases.

Literature from lower grades indicates that teachers' content knowledge has gaps as well. Rice (2005) studied the content knowledge of 400 pre- and 70 in-service elementary science teachers. Rice found that 74% of the teachers knew that an electron is smaller than an atom and only 4% could properly explain what a molecule is. 50% of the teachers indicated that oxygen, like water boils at 100 ºC.

Canpolat, Pinarbasi & Sözbilir (2006) indicated that pre-service teachers harbour misconceptions that were similar to those of learners. The authors explained that teachers in their study were of the view that liquids need to be heated for vaporisation to occur and vaporization normally occurs when a liquid boils, a similar view held by learners.

In summary, the reviewed literature indicates that it is important to measure and to understand the consequences of teacher knowledge with regard to teaching and learning. While numerous models describe teacher knowledge and various strategies to measure it, investigations show that PSTs' knowledge is unsatisfactory in most cases (Aydin & Boz, 2012). This is a cause for concern because literature suggests that teachers without adequate knowledge tend to treat complex concepts superficially (Harlen, 1997, cited in McConnel *et al.*, 2013) and their ideas about science content may not represent accurate conceptions (Akerson, 2005). The inadequate knowledge could possibly lead to anxiety and low levels of teacher self-efficacy, which may result in ineffective teaching and learning of science. It is worth noting that most of the literature on teacher knowledge for both PSTs and in-service teachers has concentrated on middle grades and literature concerning higher grades is limited. Thus, the present study measures the knowledge of physical science PSTs in the FET phase as an indication of their competence, using a strategy similar to concept inventories.

One thing that is not clear in the current literature is how all these categories of knowledge as conceptualised by Shulman and others guide teachers' actions in the classroom. The development of such knowledge will assist the education community in comprehending the internal processes that underpin the teachers' application of theoretical knowledge in practice.

2.4 Teacher beliefs

Literature has moved away from investigating relationships between teachers' skills and learner learning to the thought processes that influence teachers' actions and decisions in a classroom (Tanase & Wang, 2010). Teachers have to make many decisions in a teaching and learning situation and some of these decisions are dependent on teachers' beliefs systems (Ucar & Sanalan, 2011). Teacher beliefs are an important aspect for understanding teacher behaviours. They assist in the design of robust teacher educations programmes that help shape teacher thinking and practices (Richardson, 1996). Wasserman and Walkington (2014) argue that the focus of policy makers, educators and researchers should be on novice teachers' beliefs regarding instruction instead of expert opinions. A litany of literature exists that shows that the teaching and learning of a subject is significantly influenced by teachers' beliefs about the subject (Bryan, 2012; Mansour, 2009; Tanase & Wang, 2010). The teaching of physical science is no exception (Bryan, 2003; Cheng, Chan, Tang & Cheng, 2009; Mansour, 2009; Tanase & Wang, 2010). Korthagen (2004) went so far as to consider beliefs the most important aspect of the teacher education literature. Pajares (1992) also suggests that beliefs are a stronger predictor of teacher classroom behaviour than subject matter knowledge.

Numerous definitions have been offered with respect to teachers' beliefs about learners, the teaching and learning process and the academic teaching material, but there is still much discord over the definitions. The definitions have been described under the guise of other constructs such as attitude, judgements, opinions, values, etc. This led Pajares (1992) to describe teacher beliefs as a messy construct, mainly because beliefs do not readily subject themselves to empirical testing. Pajares (1992: 307) further argues that "the difficulty in studying teachers' beliefs has been caused by definitional problems, poor conceptualisations, and differing understandings of beliefs and belief structures." Mansour's (2009) view is that teachers' beliefs cannot be defined clearly and there is no one correct conceptualisation of the construct. This is because beliefs tend to be more *experience-based* than *theory-based*.

While literature indicates that there is much variation with regard to the definition of teacher beliefs, there are however widely accepted assumptions about the nature of teacher beliefs (Bryan, 2012). They include the following:

- Beliefs have more influence than academic knowledge in making teaching decisions, framing, analysing and problem solving.
- Some beliefs are more strongly held than others are, resulting in a core set of beliefs, which are believed to be more resistant to change.
- Beliefs are interdependent and they are arranged in system that have an important psychological effect on the individual.
- A change in one of the beliefs will likely have an effect on the whole system of beliefs.
- Individuals may have similar or competing beliefs regarding a similar topic.

With regard to pre-service teachers, the argument is that their beliefs are shaped by the content they are exposed to and their experiences regarding the content (Kazempour & Sadler, 2015).

2.4.1 Pre-service science teachers' beliefs

Scholarship points out that PSTs' beliefs have an effect on how and what they learn in their training programmes (Luft, 2009; Roehrig & Luft, 2003; Wilson, Floden & Ferrini-Mundy, 2001). Pre-service teachers' beliefs determine their acquisition and interpretation of knowledge and subsequently, they affect PSTs behaviour in the teaching situation (Pajares, 1992). Numerous researchers concur and posit that PSTs' beliefs act as a filter with which they process teacher education content and experiences (Kagan, 1992; Kutálková, 2017; Lortie, 2002; Tondeur *et al*., 2016; Veal, 2004).

Pre-service science teacher beliefs have been categorised in many ways, depending on what is being studied in the literature. The present study's interest concerns beliefs PSTs have about the teaching and learning of science and their perceived preparedness to teach. It should be remembered that one of the aims of the present study is to determine whether PSTs' beliefs are influenced if at all, positively or negatively by teacher education preparation. The present study adopts a stance by Aguirre and Speer (2000) where they look at beliefs that influence teaching and learning as belief bundles. The authors state that belief bundles refers to a collection of beliefs (e.g. beliefs about learning science, beliefs about science achievement) that are connected to one another and which influence teacher outcomes. Similarly, the present study looks at the manner in which PSTs' belief bundles are influenced by teacher education. The present study is guided by literature on science teacher beliefs and the TEDS-M framework. PSTs' belief bundles for the present study consist of beliefs about (i) the nature of science; (ii) learning science; (iii) science achievement; (iv) preparedness for teaching; and (v) programme effectiveness.

2.4.1.1 The nature of science

The understanding of the nature of science is considered an essential part of teaching science. Teaching science should not only consist of the transference of theories, laws and facts, but it should sensitise learners on how scientific knowledge is generated, developed, how it changes over time and its relationship to society (Turgut, Akçay, İrez, 2010). Over the years, researchers have come to agree on what should constitute the teaching of science at school level (Ryder, Leach & Driver, 1999; Schwartz *et al*., 2009). The consensus in this case is that teachers should sensitise learners about science's (i) empirical nature; (ii) tentativeness; (iii) theory-laden nature; (iv) creativity and nature; (v) hypotheses, theories and laws; and (vi) sociocultural embeddedness (Abd-El-Khalick, 2013; Schwartz *et al*., 2009; Turgut *et al.*, 2009).

2.4.1.2 Learning science

This category has to do with teachers' conceptions about behaviour, mental activities and the processes involved in learners' learning of science (Monsour, 2009). The present study's interest here concerns PSTs' beliefs about how learners learn science. The prevalent view with regard to learning science is that learning is enhanced if the teacher adopts constructivists' ideas about teaching (Cheng *et al.*, 2009). Effective learning therefore occurs when learners are exposed to hands on laboratory activities, environments with a high degree of cognitive involvement, problems that activate higher order thinking and cooperative teaching strategies to name a few (Wallace & Kang, 2004). In this age of major technological advancements, the teaching of science needs to be relevant to learners' everyday experiences and contexts (Monsour, 2009).

2.4.1.3 Science achievement

Teachers' beliefs regarding learner achievement are also important. Bandura's (1993) study suggests that the belief that learners can be taught will likely affect learner achievement positively. Bryan and Atwater (2002) reviewed literature about beliefs and they found that teacher beliefs about gender, race, language, learner effort and abilities influence the decisions teachers make in the classroom. The authors found that teachers believe that learners from culturally diverse backgrounds are not as capable in physical science as others are. Gomez (1993) as cited in Bryan and Atwater (2002) further asserts that such negative beliefs hamper effective instruction in classrooms. It is therefore important to understand PSTs' beliefs and to sensitise them on issues of inclusivity and diversity.

2.4.1.4 Preparedness for teaching science

The category determines pre-service teachers' perception regarding their preparedness as a result of engaging in teacher education. PSTs' views of whether the program capacitated them sufficiently to carry out the daily duties of teaching in their first year of teaching are assessed. The focus is mainly on pre-service teachers' teaching skills such as conducting assessments, managing learning environments and engaging learners in effective learning (Schwarz & Gwekwerere, 2007).

2.4.1.5 Programme effectiveness

The category refers to the beliefs that teachers have about the overall effectiveness of their teacher education programme. The category determines whether pre-service teachers believe that their respective programmes were helpful in assisting them to learn how to teach physical science. In Tatto *et al*'s (2012) view, this category assesses whether lectures modelled good teaching practices and PSTs' beliefs about lecturers' predisposition towards the promotion of reflection, research and evaluation in their courses. The category further assesses if teacher educators valued pre-service teachers' experiences before and during their training.

2.4.2 Studies investigating teacher beliefs

Numerous scholars have explored teacher beliefs, including pre-service teacher beliefs, in detail. The challenge with reviewing pre-service teacher beliefs, or any type of beliefs for that matter, is that they largely depend on the context or culture of a country or institution (Blomeke & Kaizer, 2014). Nevertheless, some of the studies have produced interesting results.

Unlike experienced teachers' beliefs which tend to be stable (Bryan, 2012), PSTs' beliefs have been shown to be unstable, disconnected and not well developed (Wallace, 2014). Simmons *et al* (1999) studied the beliefs of 116 novice science teachers in the US and the authors discovered that PSTs beliefs wobbled between learner-centred and teacher-centred approaches. Although PSTs considered their teaching to be learner centred, their actual practices in the classroom tended to be more teacher centred.

PSTs' beliefs about science and its teaching influence their decisions with regard to the adoption and implementation of inquiry-based strategies in classrooms (Crawford, 2007). In her qualitative study, Veal (2004) contests that background contexts such as academic and practical experiences with science influence the knowledge, beliefs and the manner in which novice teachers translate science to the learners. Veal (2004) also suggests that beliefs may act as a filter for PCK, which in effect means that beliefs guide how teachers learn.

PSTs place great emphasis on the need to keep learners well managed and engaged, irrespective of their beliefs about effective science teaching and learning. Talanquer, Novodvorsky and Tomanek (2010) discovered that novice teachers in the US selected activities for their lessons based on goals such as development of process skill in science, learner motivation and engagement in structured science activities. The authors lamented that the adoption of these goals in the early years of the PSTs' careers may lead them to value minimising classroom disruptions over designing lessons that focus on conceptual learning. Similarly, Capel (2001) discovered that novice teachers were mainly concerned with issues involving classroom management in the beginning of their careers.

Some of the research has focused on PSTs' epistemological beliefs and self-efficacy. Yilman-Tuzman and Topcu (2008) studied the relationships between epistemological worldviews, epistemological beliefs and self-efficacy beliefs of Turkish PSTs. The authors reported that PSTs' beliefs were not well developed and their scores for some aspects of epistemology differed significantly. For instance, they exhibited sophisticated beliefs about the innate ability, which means that they believed learners' intelligence is not fixed and it can be enhanced through good teaching practices. However, their beliefs about simple knowledge and certain knowledge were less sophisticated. PSTs held positive beliefs about learner centred approaches to teaching but they believed that learners should be encouraged to memorise facts and laws.

PSTs hold desirable beliefs about inquiry-based learning but they do not possess the necessary knowledge to carry out this sort of learning in the classroom. Boz and Uzuntiryaki (2006) found that chemistry PSTs' beliefs were not consistent with constructivists ideas about teaching after undergoing teaching practice. They also discovered that even if PSTs held desirable beliefs about learner centred approaches and strategies, they did not exhibit an intimate understanding of how the approaches and strategies promote teaching and learning. Backhus and Thompson (2006) further found that even if PSTs hold desirable beliefs about the nature of science, they are unable to apply the methods adequately in practice.

In her study, Erbe (2000) discovered that similar to numerous studies, learner achievement was affected by their socio-economic status (SES). She also discovered that teachers' beliefs regarding learners and their parents accounted for almost a quarter of the variance in learner achievement. She went on to note that the belief that there are limitations to learner capacity to learn has an undesirable influence on learner achievement (Erbe, 2000). Georgiou and Tourva (2007) also found that teachers believe that learner achievement is primarily influenced by attributes such as intelligence and has very little to do with effort on the learners' part.

In summary, literature shows that PSTs' beliefs are not stable and they emphasise control of learners more than engaging learners in meaningful active learning (Talanquer *et al.*, 2010). Some studies indicate that PSTs hold sophisticated views about teaching such as learner-centred teaching methods, but they also believe in memorisation of laws and facts (Yilman-Tuzman & Topcu, 2008). PSTs also correctly believe that inquiry-based methods lead to better leaner achievement, but they lack the ability to use these methods in practice (Boz & Uzuntiryaki, 2006; Wallace & Kang, 2004). Scholarship therefore seems to suggest that teacher education programmes are not effective in changing PSTs' beliefs for the better. This is a cause for concern because they may draw on the way they were taught, which may not necessarily be desirable. The present study will therefore assess the PSTs' beliefs and determine whether the OTL they were exposed to affected their beliefs.

2.5 Opportunity to learn

Klieme *et al* (2008) argue that if competencies are seen as context-dependent ability constructs, then they can only be acquired through a learning process where there is interaction with the learning environment. More importantly, the authors argue that competencies can be attained and influenced through experiences gained in relevant situations. The development of the desired knowledge and beliefs is only possible when teachers are exposed to relevant situations that allow them to improve their attributes (Heafner & Fitchett, 2015; Litman *et al.*, 2017). Therefore, teacher competence largely depends on whether teachers had the opportunity to interact with the knowledge and the environment to develop the desired beliefs, knowledge and skills, i.e. if teachers had the opportunity to learn (Floden, 2002; Schmidt *et al.*, 2011).

International comparative tests in mathematics conducted under the auspices of the International Association for the Evaluation of Educational Achievement (IEA) have focused on the relationship between OTL that learners are exposed to and educational achievement. Their argument is that learners cannot be assessed on a particular topic or unit of work without knowing if the learners had the opportunity to study it thoroughly (Tornroos, 2005). Clearly, it is of no use when one assesses learners on content that is not taught in one country and compares the findings of that country with another country where the topic or unit of work is taught (Schmidt *et al.*, 2011). This would indeed invalidate the results.

OTL is essentially a set of generative concepts that have altered how teachers, researchers and policymakers approach the question of varying learner achievement (Mo, Singh & Chang, 2013). The power of the OTL concept was realised when scholars noticed that much of the variance in learner's achievement scores could be explained by the OTL that learners were exposed to in specific countries (Schmidt *et al.*, 2011). This idea is equally suitable for teacher education, because the knowledge, skills and beliefs teachers display in the workplace are influenced directly or indirectly by the OTL afforded to them in their respective TEIs. OTL therefore represents a specific vision of what effective teacher education should be and what teachers should be able to do in class in order to display competence (Schmidt *et al.*, 2008).

2.5.1 Different views on the concept of OTL

In 1963, John B. Carroll proposed a model to explain the variance observed in foreign languages achievement scores. Carroll argued that learners' achievement was affected by variables such as aptitude, perseverance, quality of instruction, ability to understand instruction and opportunity to learn (Carroll, 1989). Carroll's model changed the focus of learning from what the learners can learn to how long it will take learners to learn (Kurz, Talapatrab & Roach, 2012). The variables as stated by Carroll emphasise two things. Firstly, learners should be allocated sufficient time to learn and master a certain task and secondly, the quality of instruction should be of an acceptable standard to allow learners to interact with high-quality educational resources and to direct their own learning. Tornroos (2005) explains that one of the factors that determine learner achievement is whether the learners have had the opportunity to learn a particular topic or task. The author argues that if learners have not had the opportunity to study a unit of work, they may transfer knowledge from other learning areas or related topic to formulate a solution, which in most cases may not be the correct one.

Researchers and organisations have refined the concept and some have developed their own understanding of the OTL concept. For example, Reeves and Muller (2005) define OTL as the degree to which what is tested relates to what is taught. On the other hand, Wang (1998) defines OTL as comprising two dimensions, namely the quality and the amount of exposure to new knowledge. Wallace (2009) conceptualises OTL as classroom events that enable the learner to acquire the expected skills and knowledge. Reeves and Muller's (2005) definition describes a traditional view of OTL, while Wang's (1998) and Wallace's (2009) definition can be viewed as a sociocultural view of OTL. The present study views OTL as the total amount of experiences that are afforded to PSTs in order to promote their competence.

Organisations such as IEA that specialise in international comparative tests classify OTL into three categories namely, the intended, implemented and the attained curriculum (Blomeke *et al*., 2014; Schmidt *et al*., 2011). In the IEA case, OTL can be measured as the amount of time a teacher intends to spend on a topic (intended curriculum), the actual time a teacher spends on a topic (implemented curriculum) and if the learners possess sufficient knowledge about the topic (attained curriculum) (Schmidt *et al.*, 2011). The intended curriculum does not strictly represent OTL, because it is a measurement of what the learners are expected to learn, not what they have learned.

What is defined and accepted as OTL, ranges from the time learners have to study a unit of work, the resources that the teacher uses, the proficiency of the teacher, and the resources that are available at the school. One may say that among other classifications, OTL can be regarded as occurring at the learner, teacher and the institutional level (Moss *et al.*, 2008). Hence, researchers and policy makers have expanded the concept to include school conditions, the quality of resources, curricula and the teaching that learners experience (Kurz *et al.*, 2012; Mo *et al.*, 2013). The present study is based on this argument as well. It is likely that teacher preparation programmes expose future teachers to different OTL due to teacher educators, curriculum, resources and institutional differences and as a result, what PSTs learn may ultimately depend on these variables.

2.5.2 Measurements of OTL

Over the last four decades, OTL has been used extensively in international comparative studies, at least for explaining the achievement gaps in the teaching and learning of mathematics and science (Blomeke & Kaizer, 2014). There have been numerous positive associations between OTL and learner achievement in the literature, giving rise to extensive research on the relationship between schooling and learner achievement (Schmidt *et al.*, 2011).

Floden (2002) summarises the different conceptualisations of OTL from the literature and each one of the conceptualisations has variables which are similar and some which are unique to a specific conceptualisation. In the next section, I briefly discuss the different ideas that inform the measurement of OTL in the literature.

2.5.2.1 Content coverage

Content coverage is one of the most studied variables of OTL, simply because it is embodied in most definitions of the concept and because it is said to be a powerful predictor of learner success (Reeves & Major, 2012; Reeves & Muller, 2005; Tornroos, 2005). Content coverage is normally measured by observing classroom instruction, assessing teacher self-reports and analysis of curriculum materials (Reeves & Major, 2012). This methodology was used in 1995 by the TIMSS curriculum survey where they requested teachers to give an indication of the topics they covered in their instruction. Interestingly, the same study also showed that teacher self-reports were reliable measures of the content they taught. Content coverage can also be measured by analysing textbooks as in the case of Tornroos (2005). Although textbook analysis does not indicate whether the teacher actually taught the topics in class, it however provides a general picture of how the topics are packaged in a course or learning area.

2.5.2.2 Content exposure

Content exposure is measured by observing classroom instruction where the actual time spent on instruction of a specific content is assessed (Long, 2014). Terms such as academically engaged time, amount of time in class, instruction time and time devoted to a subject are all synonymous with the measurement of content exposure. Literature suggests that learner learning is strongly influenced by the time they spend on task (Cooper, Robinson & Patall, 2006). To measure content exposure, teachers are usually requested to indicate the number of periods they devote to a topic (Kurz *et al.*, 2012).

2.5.2.3 Content emphasis

Teachers are normally requested to indicate their treatment of content area; whether they treat it as a major or a minor topic, or whether the topic was not taught at all. Other scholars have investigated content emphasis in terms of breadth and depth of content taught (Schwartz *et al.*, 2009). Time spent on a topic is categorised in terms of breadth and depth where prolonged amounts of time interacting with a topic are regarded as 'deep learning' and interactions with numerous topics are regarded as 'breadth learning' (Schwartz *et al.*, 2009). The present study views OTL tertiary subjects as deep learning and OTL school subjects as breadth or surface learning.

2.5.2.4 Quality of instructional delivery

Quality of instruction is measured through classroom observations and teachers are normally rated on effective presentation of teaching material; their organisation of activities to meet the educational objectives; and whether they had well-formulated objectives. The quality of instructional delivery was measured in a study by Stevenson and Stigler (1992) through direct measurements. The authors compared the quality and the learning gap between the US, China and Japan. The study examined how learners' errors were used in the classroom and issues around instructional coherence, the quality of interaction between learners and teachers, and the pace of instruction were also examined.

The present study draws from Carroll's model for explaining the variance in achievement and Floden's (2002) conceptualisations with regard to the measurement of the OTL that PSTs are afforded in their teacher education programmes. The conceptualisation of OTL that the present study adopts is similar to the one employed by TEDS-M study, as it integrates Carroll's and Floden's ideas to provide a more holistic view of OTL afforded to PSTs in their teacher education programmes. The conceptualisation used in the present study includes measurements of OTL school-level physical science, OTL tertiary-level physics and chemistry, OTL science education/pedagogy, OTL through reflection, OTL through teaching practice and OTL in a coherent programme. The conceptualisations are briefly described further in Chapter 3.

2.5.3 International comparative evaluation perspectives on OTL

The concept of OTL is used in international comparative evaluations for explaining the differences in learner achievement using a variety of variables that may influence learner learning within and across countries (Mo *et al.*, 2013). Policymakers and scholars are generally interested in determining factors that affect learner performance, be it good or poor. The first obvious question to be asked is if the learner had the opportunity to study the content because this will guide researchers in determining if there is a need to investigate other factors besides OTL. One other factor of interest is the relative emphasis of the topics in the curriculum (Schwartz *et al.*, 2009). If for instance, learners in Botswana perform better in algebra than learners in South Africa do, it is reasonable to assess whether the learners in Botswana had more opportunities to interact with the topic than the learners in South Africa had. In the case where it is determined that learners in Botswana do more algebra topics than the learners in South Africa do, it may be suggested that the number of topics in algebra may help explain the differences in achievement.

Unfortunately, international comparative tests have one main drawback, which can be seen in most of the participating countries. The media, private organisations and, in some cases, researchers tend to turn these tests into what Floden (2002) refers to as ‘cognitive Olympics’ where winners and losers are determined. It is also quite common in South Africa to hear media reports regarding the poor performance of learners in mathematics and science, and how the education system is failing as a result. While the intention is not to try to defend the country’s poor performance in these tests, the results should be regarded as a tool to help us improve where we lag behind and not as a tool to crucify the education system. The tests should be seen as offering insights into the processes of education in a specific country (Schmidt *et al.*, 2011). The current study follows this argument as well. The aim is not to find the best institution for preparing science teachers but to determine the OTL that lead to science teachers with adequate knowledge and desirable beliefs regarding teaching and learning.

A lot can be learned from international comparative studies. It is possible to learn about school organisation, teaching process and other educational aspects of countries with high-achieving learners. This will enable other countries to improve their education system without trying to copy the practices of countries with high learner achievement, which, in most cases, may not be suitable for another country (Tornroos, 2005). The similarities and differences in OTL that emerge from such tests give an indication of what other learners from different schools, institutions, states, countries and with different teachers are learning.

2.5.4 OTL during science teacher preparation

There are debates about how to prepare PSTs effectively for the challenges they will face in the classroom (Cofré *et al.*, 2015; Evagorou *et al.*, 2015; Liu *et al.*, 2015). The debates are mostly based on what should constitute an effective science-teacher education programme (Boyd *et al.*, 2008; Wilson, 2011).

Science teachers have been prepared for decades and while there are suggestions on how the programmes in TEIs should be packaged, literature on the intricacies of science teacher preparation programmes is sparse (Ucar & Sanalan, 2011; Wilson *et al.*, 2001). The limited literature on science teacher preparation programmes suggests that the programmes have little or no research-based evidence of their effectiveness (Cochran-Smith & Zeichner, 2005; Luft *et al.*, 2003). In the midst of these uncertainties regarding how science teacher education should be packaged and delivered, one thing that researchers seem to agree on is that PSTs should be trained to teach science using reform goals (Akcay & Yager, 2010; Wilson, 2011).

Reform goals refer to teaching science using argumentation, inquiry and problem-based learning, coupled with teaching and learning methods that are relevant to learners' everyday lives and cultures (Aydeniz & Kirbulut, 2014).

The Minimum Requirement for Teacher Education Qualification (MRTEQ) policy document provides a framework for teacher preparation in South Africa (Department of Basic Education, 2015). The document also goes on to elaborate on the necessary competencies that a beginner or novice teacher should possess. According to the said document, a teacher qualification should comprise 480 credits minimum, of which 240 is reserved for subject-specific knowledge (physical science CK and PCK). The last point brings to the fore the emphasis that is placed on subject-specific knowledge by the framework. The document further states that a novice physical science teacher should be competent in both physics and chemistry, and one of the subjects must at least be at National Qualifications Framework (NQF) level 6 and the other at NQF level 7. For example, a prospective teacher should have completed chemistry at first-year level and physics at second-year level to be a physical science teacher at FET phase.

The assumption is that all the TEIs in South Africa are guided by the MRTEQ document, but little is known concerning the effectiveness of the knowledge mix in preparing competent novice teachers. Moreover, the document does not indicate the type of content that should be taught to PSTs, i.e. if PSTs should be exposed more to university or school-level science. The present study looks at these issues as the findings may assist policy makers to design effective and responsive teacher education programmes.

2.5.5 Comparisons of teacher attributes

The importance of the role of teachers regarding differences in learner achievement was highlighted in the TIMSS study (Schmidt *et al.*, 2001). Given the role teachers play in the organisation of the day-to-day tasks in terms of teaching and learning, researchers started to wonder if some of the perceived differences can be explained by teacher attributes. One of the teacher attributes that researchers concentrated on was the issue of teacher knowledge and, at a later stage, teacher beliefs.

The TEDS-M study under the aegis of the IEA sought to fill this gap by determining whether and how teacher education contributes to teacher competence using a sample of primary school PSTs (Blomeke *et al.*, 2012). The TEDS-M study offered the opportunity to determine the relationship between teacher knowledge, beliefs and teacher education programmes across different countries. Initial analysis of the results indicated that there were significant differences in PSTs' background and OTL they were exposed to during their training. Differences in the outcomes measures such as mathematics pedagogical content knowledge and mathematics content knowledge for these countries were also identified (Blömeke, Kaiser & Lehmann, 2010). Of importance to the present study is that the findings indicate that there are significant differences in OTL and the subsequent outcome measures mentioned above between institutions in the same country (Schmidt *et al.*, 2011). As this seems to be the case for mathematics teacher education in the USA, it remains to be seen if this is also the case for science teacher education in South Africa.

2.6 Relationships between beliefs, knowledge and OTL

Research regarding PSTs should, as one of its focus areas, investigate and explore the effects of different experiences offered by teacher education programmes on PSTs' beliefs and knowledge (Boyd *et al.*, 2009; Koc, 2012; Roychoudhury & Rice, 2013; Tillotson & Young, 2013). Unfortunately, there are a limited number of such investigations in the current literature and this will always call into question the so-called 'obvious' link between teacher training and teacher quality. Of the available literature, the findings tend to vary according to learning area (Wilson *et al.*, 2001), which simply suggests that findings from one learning area cannot be readily generalised to another one. Although this is so, I reviewed literature from mathematics education to supplement the literature in science education.

2.6.1 OTL CK and PCK

There are studies that indicate a positive relationship between OTL CK and PCK, and PSTs' performance in the classroom (Boyd *et al.*, 2009; Cetin *et al.*, 2014; Loughran *et al.*, 2004). What is also evident in the literature is that OTL methods and content courses are good predictors of teacher knowledge and performance in some cases (Santau *et al.*, 2014).

Schmidt *et al* (2011) found that there was a significant relationship between pre-service mathematics teachers' knowledge and the OTL they were exposed to. OTL advanced topics in mathematics including calculus was found to be related to pre-service mathematics teachers' scores on functions, algebra, data and number geometry (Schmidt *et al.*, 2011). Ingvarson *et al* (2007) also indicate that the OTL content-related courses such as science related content and pedagogy helped to explain the variance observed in the PSTs' knowledge scores. An interesting case about content courses is reported by Palmer (2008). The author reports that the chemistry lecturer in the study customised the course to include some pedagogical aspects in that PSTs were encouraged to use household items when performing experiments. The PSTs were free to design their own experiments that they could likely do at schools that have a shortage of resources. The PSTs in this study indicated they valued this sort of approach because it assisted with bringing content and pedagogy closer.

Schmidt *et al* (2011) also found that pre-service curricular knowledge improved when they had the OTL the history of mathematics. The OTL mathematics pedagogy, including how learners learn and solve problems, was significantly related to pre-service teachers' knowledge of learners. Additionally, some scholars (e.g. Baumert *et al.*, 2010; Friedrichsen *et al.*, 2009; Rollnick *et al.*, 2008) indicate that the OTL content of a subject greatly enhances the PSTs' PCK as suggested by Shulman (1986; 1987). Daehler and Shinohara (2001) also found that PSTs PCK is enhanced by the number of methods courses taken.

There seems to be no definitive indication of the amount of CK and PCK needed for PSTs to be effective teachers, but there are indications that there is a threshold effect in terms of the amount of courses taken. Monk (1994) found that more than five content courses in the PSTs' training had little effect on learner achievement. Additionally, PSTs' PCK and CK were significantly related to the number of mathematics related courses/topics they took.

There are a few studies that indicate that PSTs' beliefs with regard to teaching and learning change as a result of interaction with knowledge. A study by Anderson, Smith and Peasley (2000), and Tanase and Wang (2010) shows that middle-grade PSTs' beliefs change to appreciating learner centred approaches after interactions with some content focused courses in their respective programmes. Macugay and Bernardo (2013) found that secondary science teachers were less likely to support the notion that physical science achievement is associated with learner ability and this finding may be attributed to the higher number of content-related courses they were exposed to. Furthermore, the same authors found that PSTs who have more science-related courses are less likely to espouse cultural beliefs. Cultural beliefs in this instance are beliefs about physical phenomenon, natural environment, and human and health development.

Roychoudhury and Rice (2013) have found that content courses assist PSTs in being accommodating and attentive to learners' learning needs from diverse groups. The authors further note that this represents an epistemological shift from regarding one's self as a model of a learner to embracing other learners as models. In their paper, Ucar and Sanalan (2011) report that beliefs with regard to the teaching of science seem to be related to the number of science courses taken, although the trend is not conclusive. Similarly, Macugay and Bernardo (2013) report that teachers approve of the learning-support model of teaching when exposed to more science courses, suggesting that PSTs adopt the learner-centred orientation when exposed to more science related courses.

When PSTs take more science-related courses, their beliefs tend to be desirable and, in some instances, they tend to be undesirable. The Investigating the Meaningfulness of Preservice Programs Across the Continuum of Teaching (IMPPACT) study as captured in Tillotson and

Young (2013) show that content modules did little in preparing PSTs for the classroom but their methods' modules, if presented in sequence over their years in training, helped them to engage with and to select appropriate inquiry-based strategies for teaching. Tatar (2015) also shows that if inquiry methods are incorporated in PSTs' methods' courses, they develop desirable beliefs about using inquiry methods to teach science.

2.6.2 OTL through reflection

Reflection is regarded as one of the goals of teacher education as captured in the literature (Tatto, 2007). In fact, there are claims that reflection plays a major role in defining a teacher as professional and not a technician. Although implicit, it can be argued that the notion of reflection embodies what Shulman (1986) had in mind when he proposed the concept of PCK. Scholars therefore suggest that one of the goals of teacher education is to prepare reflective practitioners (Etscheidt, Curran & Sawyer, 2012). However, there seems to be a paucity in literature on the effects of reflection on teacher outcomes. This has led to some scholars criticising the idea because of the insufficient literature to substantiate the link between reflection and teacher outcomes as well as learner outcomes (Collin, Karsenti & Komis, 2013; Thompson & Pascal, 2012). Some scholars have even questioned the value of reflection in teacher education citing that there is little in terms of empirical evidence that points towards the impact of the concept on teacher and learner outcomes (Mälkki & Lindblom-Ylanne, 2012; Russell, 2013). Other scholars argue that there is more talk about reflection in teacher education than the actual practice of reflection (Beauchamp, 2015).

2.6.3 OTL through teaching practice

Field experiences are considered to be an influential part of teacher preparation according to the literature (Hollins & Guzman, 2005). While a number of studies do provide an indication of benefits for PSTs, few studies indicate the manner in which the practicum enhances teacher knowledge and beliefs. The problem may be that it is difficult, methodologically speaking, to design a study that would test this claim reliably; hence, most of the literature relies on small-scale qualitative studies (Ronfeldt, 2012). This problem is further exacerbated by the notion that field experiences that PSTs are exposed to in schools differ widely. It would therefore not be proper to generalise the findings, because of the context- and quality-laden nature of the field experiences. One of the few studies that attempted to link field experiences and education outcomes was carried out in New York City by Boyd *et al* (2009). The study focused on linking the type of placement while on field experience and PSTs achievement. The study claimed positive associations between the two. Field experiences in this context refers to when PSTs are placed in a school where there is oversight of teaching practice and where they have the opportunity to teach a class. In the same sense, Schmidt *et al* (2011) show that practical teaching experience, coupled with advanced mathematics knowledge, is related to pre-service teachers' knowledge of teaching and learning. The same study also shows that PSTs are likely to engage in reform-based practices if their mentors at school display instructional practices and pedagogical beliefs that are supportive of the mission of their teacher education programme. Interestingly, Consuegra, Engels and Struyven (2014) report that field placements do not afford the opportunity for PSTs to enhance their subject matter expertise.

A strong theme emanating from the practicum literature is that PSTs and novice teachers continually express how difficult they find the process of integrating what they learn in their programmes with what they are expected to perform in schools (Ingvarson *et al.*, 2007; Tillotson & Young, 2013). This may be because of the current climate at universities where teacher educators are expected to perform numerous tasks in conjunction with their main task, which is to train future teachers. This situation has far-reaching implications in terms of the experiences that are offered to PSTs in that the conditions of learning are less optimal when there is no integration of theory and practice (Buzza, Kotsopoulos, Mueller & Johnston, 2010; Yuen, 2011).

An interesting finding in Ingvarson *et al*'s (2007) study is that teaching practice features such as time spent teaching, whether PSTs did teaching practice in blocks and the perceived effectiveness of the practicum were not significantly related to PSTs' preparedness for teaching. The authors were however quick to point out that this was not to say teaching practice was not an important feature for teacher education programmes, but it might be a case where the PSTs' experiences at schools were not positive.

Scholars have investigated the effects of teaching practice on PSTs' beliefs. In Koc's (2012) study, PSTs reported that mentoring teachers were not effective in creating conducive environment for PSTs to learn and develop their teaching skills. This inherently affected the PSTs' belief bundles negatively. The study suggests that the PSTs are not afforded the opportunity to bring the two types knowledge, i.e. theoretical and practical to a space where they can reflect on the knowledge as a whole.

Some studies indicate that PSTs' belief bundles are not stable and they change with situation or context. Roychoudhury and Rice (2013) argue that most PSTs go to schools embracing learner-centred methods and approaches, but they revert to teacher-centred approaches as they are acculturated at schools. Similarly, Hancock and Gallard (2004) found that engaging in teaching practice left PSTs believing that learners learned physical science better through lecturing and memorisation. The authors also found that the reason for this shift could be attributed to suggestions by PSTs that they did not get to experience and observe learner-centred teaching methods. Davis, Petish and Smithey (2006) also found that secondary school PSTs emphasise the memorisation of facts and they believe it will lead to enhanced learner success. Sorensen, Newton & McCarthy (2012) further found that PSTs do not develop desirable beliefs about learning science if they are not exposed methods that foster these type of beliefs in practice. The trend suggests that PSTs' beliefs tend to shift after their encounter with genuine classroom situations and this warrants an investigation into the possible reasons for this behaviour.

2.6.4 OTL in a coherent programme

Coherence is considered to be the solution to some parts of teacher education that are seen to be disjointed, e.g. the gap between theory and practice (Grossman, Hammerness, McDonald & Ronfeldt, 2008). Yet, despite the promise that the concept brings to teacher education, the ingredients and recipe that make up a coherent teacher education are relatively unexplored, as Grossman *et al* (2008) note. Literature on what a coherent programme looks like or the effects of such a programme on teacher education outcomes are scarce. Only a few studies have attempted to investigate this link.

Literature indicates programme coherence has an impact on some teacher attributes. For example, Roger (2011) reports that the lack of coherence manifests itself in PSTs who are uncertain about the type of teachers they are expected to be. This means teacher education programme coherence has an effect on teacher identity. On the contrary, Canrinus, Bergem, Klette and Hammerness (2017) have found that PSTs at universities indicate that their programmes are coherent. The PSTs indicated that they were afforded sufficient opportunities to connect and comment on various aspects of their teacher education programmes. Tillotson and Young (2013) found that PSTs who were members of a cohort indicated that the experience helped shape their beliefs and classroom practice. Similarly, Canrinus *et al* (2017) found that PSTs in one flexible teacher education programme indicated that their programme was less coherent and the fact that the PSTs were not part of any cohort was referred to as a contributing factor. Teachers who graduated from teacher education programmes that featured cooperative and coherent field placements indicated that they were ready for the classroom (Tillotson & Young, 2013). The TEDS-M study shows that if PSTs experience a focused curriculum, that is, if most of the courses they take are related to the mathematics, they have better PCK scores than those that experience a broad curriculum (Blömeke & Kaiser, 2014).

2.7 Conclusion

This chapter presented the conceptual framework and some relevant literature for the study. The chapter also assisted in determining the gaps in the literature towards which the present study may contribute knowledge. The main gap is that while there are studies that investigate links between OTL and teacher outcomes such as beliefs and knowledge, features of teacher education (OTL) that provide the greatest purchase in terms of PSTs learning are relatively unexplored. This knowledge may lead to effective teacher education programmes if certain OTL are emphasised in the design and development of the programmes. The following chapter will focus on the methods that were used to gather and analyse data.

Chapter 3

Methodology

3.1 Introduction

One of the most important things when conducting research is a clear and achievable plan. Thus, a set of actions that are undertaken with the aim of answering the research questions is commonly referred to as research methodology (Johnson & Christensen, 2012). This chapter contains details about the respondents, including when, where and how data were collected. It also includes details about how the collected data were analysed.

This chapter begins by stating the focus of the current investigation, followed by the appropriate paradigm, which is post-positivism. The suitable approach and design in the said paradigm are then presented and discussed. A quantitative approach and non-experimental research design in the form of a survey (teacher beliefs and OTL) and an achievement test were employed for data collection. Issues with regard to the conceptualisation, development, validity and reliability of the instruments, analysis of the data are also discussed in this chapter.

The present study explores the relationships between pre-service science teacher knowledge, beliefs and the OTL they are afforded at some South African teacher education institutions. The study specifically assesses the opportunities to learn that significantly affect aspects of PSTs' competence as defined. To achieve this, the study sought to answer the following questions:

1. What is the level of knowledge of pre-service physical science teachers in some South African universities?
2. What are PSTs' beliefs about teaching and learning of physical science?
3. What kinds of OTL are pre-service science teachers exposed to in some South African universities?

4. What are the relationships between PSTs' knowledge, beliefs and the OTL they are exposed to?
5. Which OTL are significant predictors of multiple variables in the knowledge and beliefs constructs?

3.2 Philosophical underpinning

Philosophical underpinnings refer to beliefs a researcher draws on when taking certain actions (Creswell, 2014). The present study adopts a post-positivist stance with regard to research. Post-positivism is appropriate for the present study because it is reductionist paradigm where ideas such as teacher beliefs and OTL are reduced into small and discrete sets of data that can be tested statistically (Creswell, 2014). Additionally, the present study involves an investigation of relationships using dependent and independent variables which is similar to post-positivist methodologies. The present study therefore involves the measurement of variables, some of which cannot be observed directly.

I adopted a common philosophy of post-positivism known as critical multiplism, which emphasises that any sort of observation or measurement has inherent error (Cohen *et al*., 2007; Panhwar, Ansari & Shah, 2017). In line with the philosophy, I employed the technique of multiple measurement and triangulation methods to approximately describe reality (Creswell, 2014). According to critical multiplism, the goal of engaging in scientific investigations such as the present study's investigation is to try to describe reality to the best of our ability, even though one can never describe it completely and accurately (Deluca, Gallivan & Kock, 2008).

3.3 Research approach

The appropriate research approach is chosen because of its ability to generate appropriate data to answer the research questions and, as such, the research approach chosen is dependent on the research questions. Considering the chosen paradigm, I opted to use quantitative research methods. Creswell (2014) also points out that the assumptions for post-positivism are more consistent with quantitative approaches than qualitative approaches. Quantitative approach is appropriate for the present studies investigation because the approach emphasises empirical observation, measurement and theory testing. Thus, the development of numerical measures, observations and the investigations into human behaviours are important issues with post-positivists (Ary, Jacobs, Sorensen & Walker, 2014).

The present study used variables that can be ordered according to their magnitude to describe reality and it also used the confirmatory scientific method because the present study's focus is on hypothesis and theory testing (Check & Schutt, 2012). The preferred approach allows for the determination of relationships that may exist between PSTs' knowledge, beliefs and the OTL they are afforded in order to establish trends, relationships and possible differences. The preferred approach further endeavours to have data that can be replicated and results that can be generalised to a certain group such as physical science PSTs (Creswell, 2014).

It is challenging to develop and administer a qualitative instrument that can measure the beliefs and OTL of a large group of teachers effectively. If qualitative methods were to be employed, the data would be enormous and it would be difficult to categorise and analyse data for all the respondents (Cohen *et al.*, 2013). Mixed methods were not appropriate as well because the aim of the study is to determine the OTL that significantly affect PSTs competence and this can only be reliably achieved by employing quantitative methods. The approach used in the present study is similar to that used by Akpo (2012) in a study where he sought to investigate the impact of teacher-related variables on students' Junior Secondary Certificate (JSC) Mathematics results in Namibia.

3.4 Research design

A research design is essentially a plan that is followed to gather data and to answer the research questions of the study adequately (McMillan & Schumacher, 2014). I adopted a non-experimental design because the study uses correlations to determine the degree of association or relationships between PSTs knowledge, beliefs bundles and OTL that were afforded to them in their teacher education programmes (Ary *et al.*, 2014).

Surveys were used in this study to collect data because they allowed for the collection of information such as opinions, attitudes and beliefs of participants (Johnson & Christensen, 2012). I also used a combination of cross-sectional surveys and achievement tests to answer the research questions. This was done because longitudinal studies, especially in the case of PSTs tend to be problematic because after graduation, PSTs may go and ply their trade at any part of the country (Check & Schutt, 2012).

3.5 Sampling methods

Sampling methods refer to the steps that are taken by the researcher to obtain a representative sample from the target population. The next section elaborates more on the population and sample used in this study.

3.5.1 Population

The target population in the present study were pre-service physical science teachers who were in their final year of study at South African universities that offer initial teacher education. This population displays the phenomenon of interest to which I would like to generalise the finding to (Ary *et al.*, 2014).

3.5.2 Sample

A sample is a sub-set of the population that resembles the target population in the variables of interest (Johnson & Christensen, 2012). The present study's goal was to study the entire population of final-year pre-service physical science teachers in all South African TEIs. When studying every individual in a population, Johnson and Christensen (2012) argue that this cannot be referred to as a survey, but it is a census. A census is where the entire population of final year physical science PSTs is studied instead of a sub-set of the population. The most notable forms of institutions that prepare pre-service teachers in South Africa are known as traditional universities, comprehensive universities and universities of technology. Comprehensive universities in this case are institutions that offer a range of academic and vocational degrees and diplomas (DoE, 2004). Traditional universities tend to be research-intensive institutions, while universities of technology focus more on vocationally oriented education. All institutions that offers initial teacher education were invited to participate in the study.

3.5.2.1 Minimum sample size for statistical treatment

Most of institutions were unable to participate in the study due to a myriad of reasons, including the #feesmustfall[1] campaigns. This meant that the sampling plan had to be modified to resemble convenience-sampling methods where the universities that were willing to participate were included in the sampling framework. I therefore had to consider the minimum sample size for the statistical tests that were used in the study.

The minimum sample size required for statistical treatment is defined as the minimum number of respondents necessary for the results to be valid, reliable and for them to make sense (Ary *et al*., 2014). The appropriate method for calculating minimum sample size is suggested by Green (1991) and Pallant (2001) as

$$N \geq 50 + 8m$$

where

N = sample size

m = number of independent variables

The OTL construct has six independent variables and therefore the minimum number of respondents required is 98. This number is sufficient for correlations and regression analysis.

1: #feesmustfall campaign was as a result of students demanding free tertiary education in South Africa. The campaign led to some universities temporarily suspending lecturers and some were temporarily closed while negotiations between students and government ensued.

For the present study, a total of 112 responses were used for analysis as indicated in Table 3.1 below. A detailed discussion will follow regarding the final number of respondents in the missing values section.

Table 3.1: Number of respondents

University	Type of university	Number of respondents
U1	Traditional University	24
U2	University of Technology	33
U3	University of Technology	16
U4	Traditional University	39
Total Number of Respondents		**112**

3.6 Data collection

In this section, the methods that were used to collect data from different institutions are described in detail.

3.6.1 Method of data collection

I was interested in assessing teachers' beliefs, knowledge and OTL towards the end of their 4-year training. Consequently, I opted to collect the data in the PSTs' final year of training. The assumption was that in their final year of training, they would have had sufficient time to acquire knowledge and to engage in other aspects of teacher training which may have had an impact on their beliefs. Data were collected over a period of two weeks, depending on the availability of the PSTs.

Other researchers who have conducted large-scale studies mention that tertiary students including PSTs generally have trouble answering a questionnaire that is more than an hour and a half long (Tatto *et al.*, 2008). With this in mind, I tried to limit the questionnaire to the specified time, but it was difficult to measure the number of variables with sufficient number of items in them to ensure reliability and validity. The questionnaire was therefore limited to one hour but some of the variables in the original questionnaire were not assessed.

3.6.2 Gaining access to universities

Before the commencement of data collection, permission was sought from the relevant authorities in all the participating universities. I inquired about the availability of the PSTs from their lecturers or the Head of Department (HOD) because some universities send their final-year PSTs to schools for extended periods. After confirming the university’s interest in participating in the study, I then wrote a formal letter to the authorities (registrar) requesting permission to conduct research. Once access was granted, the request to conduct research and all documentation were forwarded to the ethical clearance committee or a research unit for the university.

Seven universities initially agreed to participate, but four were able to participate in the research study. The sample implies that generalisation to the entire population of final year PSTs is not possible.

3.6.3 Administration of the questionnaire

Once permission was granted, I made contact with the lecturers or the HODs who then directed me to the relevant lecturer with access to final year PSTs. The lecturer and I decided on a date that was suitable for data collection. On that specific date, I went to the institution to personally administer the questionnaire with the aid of a research assistant.

I started by introducing myself and the research assistant to the PSTs and then I explained the purpose of the research study. I then informed them of their right to informed consent, privacy and anonymity. Afterwards the respondents completed a consent form to indicate that they understood what the study was about and they agreed to participate voluntarily. In most cases, it took the PSTs an hour to complete the questionnaire.

3.7 Development of the questionnaire

The sections that follow describe the manner in which knowledge, beliefs and OTL sections were conceptualised and developed.

3.7.1 Teacher knowledge

The present study used two of the categories of knowledge as proposed by Shulman (1986, 1987). The study limited itself to measuring content and pedagogical content knowledge. These two categories of knowledge have been thoroughly investigated in the literature (Govender, 2015; König *et al.*, 2011; Mavhunga & Rollnick, 2013; McConnell *et al.*, 2013).

Physical science contains numerous topics and the time (1 hour) available did not allow for the assessment for every topic. Therefore, some topics and items from each knowledge area were chosen to represent the specific knowledge area under the guidance of the Curriculum Assessment Policy Statement (CAPS) document.

The knowledge section of the instrument was adopted from an instrument that had been developed by researchers who had sought to assess the teaching deficiencies of teachers in one province of South Africa (Mahlomaholo *et al.*, 2014). There were 40 items in the original questionnaire and they were conceptualised and developed by a team of three people (a physical science methodology lecturer, physical science master teacher and a specialist in teaching and learning of physical science). The team started by determining the type of questions that should be put to teachers and they decided to use multiple-choice questions because of the size of the sample they needed to administer the questionnaire to.

Since the questionnaire measured teaching deficiencies, the content part of the questionnaire was framed by the Grade 12 achievement technical reports. The reports discuss the areas and questions that the learners found to be difficult to answer in the final exams. The team considered the reports from three previous years to frame the items in the questionnaire. The items were also based on the six knowledge areas as described in the CAPS document. The items covered work done in Grades 10, 11 and 12.

Most of the items that addressed CK were designed in such a way that they provided an answer with some sort of explanation. This meant that the options to the questions provided an answer and further went on to give some reason or fact that supports the answer. This was done to try to differentiate between the PSTs who could recognise the correct answer only and those that could validate their response with the correct explanation. There were 18 CK items in the questionnaire used in the present study.

The PCK part of the instrument was designed to address two aspects of the concept, which were teaching strategies and learner misconceptions. Teaching strategies are considered to be important aspects of PCK that a prospective teacher will need to be successful in their teaching and learning journey (Kratz & Schaal, 2015). It should, however, be noted that, strictly speaking, there is no straightforward right and wrong answer with regard to the PCK items. Six items in total addressed PCK. The sub-categories of PCK and CK that were considered are described below.

3.7.1.1 Content knowledge

- matter and materials

Matter and classification, molecular structure, kinetic molecular theory, states of matter, organic chemistry, atomic structure, periodic table, organic macromolecules, ideal gases, intermolecular forces, optical phenomena and properties of materials.

- chemical systems

Chemical industry, lithosphere and hydrosphere.

- chemical change

Electrochemical reactions, reaction rate, energy and chemical change, physical and chemical change, acids and bases, reactions in aqueous solution, chemical equilibrium, stoichiometry, types of reactions.

- mechanics

Motion in one dimension, work, energy and power, energy, momentum and impulse vectors in two dimensions, Newton's laws, one dimensional vertical projectile motion.

- waves, sound and light

Transverse waves, transverse pulses on a string, longitudinal waves, electromagnetic radiation, sound, 2D & 3D wave fronts, Doppler effect, geometrical optics.

- electricity and magnetism

Electrostatics, magnetism, electrodynamics, electric circuits, electromagnetism.

3.7.1.2 Pedagogical content knowledge

Pedagogical content knowledge was measured in terms of

- knowledge of methods and strategies for physical science teaching and learning

Planning or selecting appropriate activities, planning a physical science lesson, development of suitable methods for indicating physical science ideas, identification of diverse approaches for solving physical science problems, linking instructional designs and didactical methods.

- learners' prior knowledge including misconceptions

Diagnosis and correction of learner misconceptions with regard to threshold concepts in physical science.

After adapting items from the original questionnaire, they were sent to authorities in the Department of Basic Education (DBE) for verification purposes. The authorities suggested some changes to some of the items in the questionnaire and the suggestions were effected accordingly.

3.7.2 Teacher beliefs

Most of the items were based on descriptions provided in Tatto *et al*'s (2008) report. The items were then adapted for physical science teachers based on teacher beliefs literature (Kazempour, 2014; Kazempour & Sadler, 2015; Kind, 2016; Luft & Roehrig, 2007; Mansour, 2013; Savasci-Acikalin, 2009; Savasci & Berlin, 2012; Tillotson & Young, 2013). The items were then grouped according to their respective categories.

The categories for teachers' belief bundles were as follows:

- the nature of science

This section assessed and explored how PSTs perceive physical science as a learning area including its structures, procedures and applications.

- learning science

This section assessed the appropriateness of instructional activities, cognition processes of learners and the purposes of physical science as a school subject.

- science achievement

This section assessed PSTs' beliefs about different strategies used to facilitate the teaching and learning of physical science, beliefs about how physical science learning occurs, beliefs about innate ability to learn physical science.

- preparedness for teaching

This section assessed the PSTs' perceptions regarding the extent to which their preparation capacitated them to teach physical science. This essentially measured the impact of teacher preparation on PSTs' perceived preparedness to carry out their main duty which is to teach.

- programme effectiveness

This section assessed the overall capacity of a teacher education programme to assist PSTs in learning to teach physical science effectively.

3.7.3 OTL

OTL that pre-service teachers were afforded were categorised according the TEDS-M framework, which is also described in Tatto *et al*'s (2008) report. The categories were as follows:

- Opportunity to learn university- or tertiary-level physics and chemistry

The items in this section assessed if PSTs had the opportunity to study important concepts in physics and chemistry. The topics that make up the physics and chemistry curriculum for PSTs at universities were compiled and they were used to determine the number of topics that PSTs studied as part of their preparation.

- Opportunity to learn school-level physical science

This section assessed the kind of school level content knowledge that PSTs were exposed in their teacher education programmes. The topics were compiled using textbooks that are used in schools and the CAPS policy document.

- Opportunity to learn physical science education/pedagogy

The items in this section explored the use of teaching strategies in physical science. The items assessed whether PSTs studied the topics as part of their preparation and the number of times they engaged in activities concerning the teaching strategies.

- Opportunity to learn to teach through reflection on practice

The items explored aspects of the development and use of teaching material including questions regarding the teaching and accommodation of diverse learners. The items focused PSTs' ability to reflect on their own practice and to develop their own teaching strategies.

- Opportunity to learn through teaching practice

This section explored teachers' experiences as they engage in teaching practice. The items focused on the time PSTs spent at schools teaching and observing lessons, and whether they were assigned a mentor or not. Moreover, the items assessed the scope of the PSTs' activities as well as whether they found the experiences helpful.

- Opportunity to learn in a coherent teacher education program

The items included in this section assessed the consistency of the programmes across various courses and the experiences they offered. In addition, the items explored PSTs expectation of their initial preparation programmes.

In summary, the present study sought to assess relationships in accordance with the Figure 3.1 below.

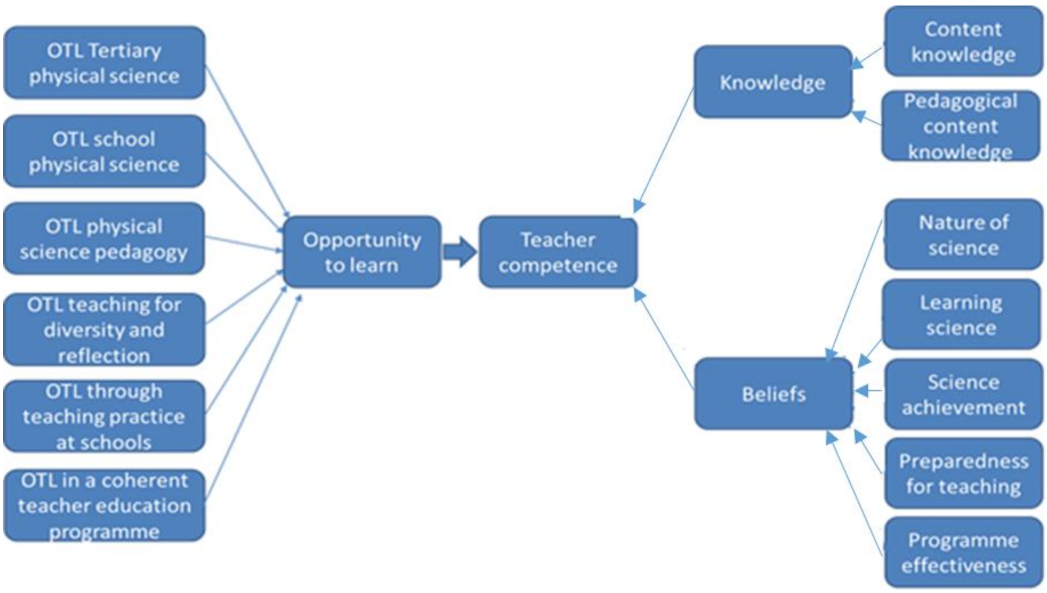


Figure 3.1: Framework for the investigation (Adapted from Blomeke & Kaizer, 2014)

3.8 Piloting

The instrument was piloted twice in 2016 with a group of 32 final-year PSTs in total. The aim of first pilot was to determine how the PSTs reacted to the original questionnaire, an hour-and-a-half to two hours long and to obtain feedback on the language used. Afterwards, I had discussions with the PSTs (nine in total). It emerged that the questionnaire was too long because the respondents took longer than two hours to complete it and others exercised their right to withdraw their participation. Based on the PSTs suggestions, the questionnaire was reduced to an hour. The items for belief bundles and OTL were reduced using the Item-Total Statistics to ensure that the best performing items are included in the instrument. Other dimensions of the OTL variables were not assessed and in some cases, the dimensions were condensed to form a specific variable e.g. the teaching practice dimensions were condensed due to time constraints. In most cases, the items were reduced to about 6 – 10 items per variable. The questionnaire was field tested with the second group (21 in total) and the achievement test's validity and reliability tests were carried out using data from this group. The knowledge test was reduced based on the distribution of the topics covered. I tried to have two items representing a learning area. The numbering of the OTL variables was kept as in the original questionnaire (before piloting) for tracking purposes.

3.9 Reliability and validity

It is essential in research to establish the validity and reliability of the research instruments as it allows researchers to determine if the collected data are credible (Ary *et al.*, 2014). Although threats to reliability and validity cannot be removed completely, they can, however, be attenuated by paying attention to some aspects of the research instruments and procedures (Cohen *et al.*, 2013).

3.9.1 Validity of the instruments

Validity is an important aspect of a research study (be it qualitative, quantitative or mixed methods) because if the study is deemed invalid, then the data and the conclusion from the data are worthless (Cohen *et al.*, 2007). The forms of validity in the context of the present study were construct validity and content validity. Earlier definitions of validity state that the instrument has to measure what it claims to measure for it to be valid but later conceptions explain that validity can be improved through appropriate sampling procedures, appropriate instruments and statistical handling of the collected data (Creswell, 2014).

3.9.1.1 Content validity

This form of validity is demonstrated when the instrument in question comprehensively and fairly covers the items or domains that it claims to investigate (Cohen *et al.*, 2013). With reference to the achievement test, it was not practical to cover each and every topic with the available time because respondents tend to lose interest when a questionnaire is longer than an hour. I then proceeded to choose and adapt items that were part of an instrument used in assessing in-service teachers' knowledge from Mahlomaholo *et al*'s (2014) study. The items were chosen according to their relative emphasis or weights in the six knowledge areas as captured in FET CAPS physical science document.

The OTL items were adapted from the TEDS-M study and the items in this section were field tested extensively (Tatto *et al.*, 2012). The researchers in the TEDS-M study subjected the field-tested items to a review by expert panels and identified any anomalies that were displayed by the item statistics. The items that did not perform well were deleted, e.g. those that had point-biserial correlations lower than 0.2 and those that displayed poor item fit according to item response theory (IRT) (Tatto *et al.*, 2012).

Numerous instruments deal with teacher beliefs in the literature but no instrument addressed all the bundles of teacher beliefs as envisaged in the present study. I then adopted sections of instruments from various studies, provided that they addressed the belief bundles adequately. Some of the belief bundles as conceptualised in the study were adapted from the TEDS-M instrument.

3.9.1.2 Construct validity

Construct validity refers to the ‘operationalised’ forms of a construct and clarifying what is meant when using a construct (Cohen *et al.*, 2013). It essentially refers to whether the items in a questionnaire relate to the accepted theoretical construct of the phenomenon in question. To ensure construct validity, I ascertained that the conceptions of the construct agreed with other conceptions of the same issue (McMillan & Schumacher, 2014). This can be ensured by correlations/comparisons with other well-established instruments that measure the phenomenon in question or by extensive review of literature with the aim of teasing out the conceptions of a construct (Cohen *et al.*, 2013). The instrument for the present study was therefore compared with other instruments such as the TEDS-M instrument and Ingvarson *et al*’s (2007) descriptions of their instrument for consistency. The items in the constructs were similar in nature and it was therefore determined that the instrument was of acceptable standard. Factor analysis could not be used because of the relatively small number respondents. Green (1991) suggests that a minimum sample of 300 respondents is required to draw credible conclusions from a statistical test such as factor analysis.

3.9.2 Reliability of the instrument

Reliability in quantitative research refers to the consistency, dependability and replicability of the collected data over instruments, over time and over groups of participants (McMillan & Schumacher, 2014). Cohen *et al* (2013:148) argue that, “for research to be reliable, it must demonstrate that if it were to be carried out on a similar group of respondents in a similar context (however defined), then similar results would be found”. The three forms of reliability common in research literature are internal consistency, equivalence and stability (Johnson & Christensen, 2010). Reliability for OTL physics and chemistry, and OTL school level physical science was ensured by equivalence i.e. comparisons with topics contained in text books and the CAPS document. The other form of reliability that concerns the present study is internal consistency. This is discussed in the next section.

3.9.2.1 Cronbach's alpha

Internal consistency in quantitative research can be established using two techniques known as the half split method or the Cronbach's alpha (Creswell, 2014). Although the two techniques are used to establish internal consistency, Cronbach's alpha is the technique used in most reports. Cronbach alphas were therefore calculated using Statistical Package for Social Sciences (SPSS 24) for variables of two constructs, namely teacher beliefs (Table 3.2) and OTL (Table 3.3). Initially, some of the variables had Cronbach alphas of less than 0.6, which was unacceptably low. Analysis of the Item-Total Statistics, which provides an alternative Cronbach alpha if some items are deleted, was done. One item in the variables with a '*' was deleted to obtain an acceptable Cronbach alpha, which is any number above 0.6 (Cohen *et al.*, 2013).

Table 3.2: Cronbach's Alpha for PSTs' beliefs

Section	**Variable**	**Cronbach alpha**	**Number of items**
1	Beliefs about the nature of physical science	0.660	6*
2	Beliefs about learning physical science	0.737	6*
3	Beliefs about physical science achievement	0.774	6
4	Beliefs about preparedness to teach physical science	0.921	10
5	Beliefs about programme effectiveness	0.899	6

Table 3.3: Cronbach's Alpha for OTL

Section	Variable	Cronbach alpha	Number of items
6	OTL physical science education/ pedagogy	0.881	10
9	OTL through reflection on practice	0.880	9
14	OTL through teaching practice	0.788	8
15	OTL in a coherent teacher education programme	0.862	6

3.9.3 Item Response Theory and Rasch analysis

A commonly used method to elucidate test reliability and validity is known as Rasch analysis. Rasch analysis was preferred for the present study because it indicates the probability of an individual choosing or getting a correct answer to an item (Howie, Long, Sherman & Venter, 2008). Rasch analysis further provided information regarding the homogeneity of the instrument, i.e. if the instrument measured a single variable or construct. MINISTEP 4.0.0 was used to analyse data using Rasch analysis.

The standardised z-score and the measure statistic were used to make judgements about the validity and reliability of the test. The z-score is a measurement of a scores relationship to the mean of other z-scores and a standardised score is considered to be valid when it is between -2 and +2 (Bond & Fox, 2007; Linacre, 2012). The measure statistic indicates the level of difficulty of the test according to the respondents (Jüttner, Boone, Park & Neuhaus, 2013). Since the achievement test in the present study consisted of two variables, namely CK and PCK, a separate Rasch analysis was performed for each one and the results are presented below.

3.9.3.1 Rasch analysis for CK items

Table 3.4 indicates the persons-measure statistic as generated by Rasch analysis for CK items. The measure statistic highlighted in red showed that most of the respondents found the test to be manageable, but nine respondents as indicated by the negative numbers found the test a little to moderately difficult. All the standard z-scores highlighted in blue were between -2 and +2, with the exception of one score, which signifies that the instrument was statistically valid.

Table 3.4: Person measure statistics for content knowledge

```
TABLE 17.1 CK - Achievement test                 ZOU970WS.TXT  Aug  2 2017 18:26
INPUT: 21 Person  18 Item  REPORTED: 21 Person  18 Item  2 CATS   MINISTEP 4.0.0
--------------------------------------------------------------------------------
Person: REAL SEP.: 1.84  REL.: .77 ... Item: REAL SEP.: 1.67  REL.: .74

         Person STATISTICS:  MEASURE ORDER
```

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
1	18	18	4.64	1.84	MAXIMUM MEASURE				.00	.00	100.0	100.0	S01
2	17	18	3.37	1.05	1.00	.3	.55	.1	.23	.19	94.4	94.4	S02
3	16	18	2.56	.78	1.17	.5	.92	.4	.17	.27	88.9	88.8	S03
6	16	18	2.56	.78	1.07	.3	.73	.2	.25	.27	88.9	88.8	S06
7	16	18	2.56	.78	1.04	.2	.80	.3	.26	.27	88.9	88.8	S07
4	15	18	2.03	.68	1.34	.9	3.48	1.9	-.12	.33	83.3	83.3	S04
5	15	18	2.03	.68	1.02	.2	.67	-.1	.36	.33	83.3	83.3	S05
9	13	18	1.26	.58	1.01	.1	1.10	.4	.37	.41	88.9	75.0	S09
8	12	18	.94	.56	1.14	.6	1.21	.6	.32	.43	72.2	73.3	S08
10	12	18	.94	.56	.82	-.7	.81	-.2	.55	.43	83.3	73.3	S10
12	11	18	.63	.55	1.04	.2	2.63	2.8	.31	.46	66.7	71.5	S12
11	9	18	.05	.54	.93	-.2	.82	-.4	.55	.48	66.7	71.7	S11
14	8	18	-.25	.55	.69	-1.4	.60	-1.2	.71	.49	88.9	72.2	S14
16	8	18	-.25	.55	.69	-1.4	.60	-1.2	.71	.49	88.9	72.2	S16
18	8	18	-.25	.55	.91	-.3	.90	-.2	.55	.49	77.8	72.2	S18
13	7	18	-.55	.56	.68	-1.4	.56	-1.3	.72	.49	88.9	73.0	S13
15	7	18	-.55	.56	1.02	.2	.98	.1	.48	.49	66.7	73.0	S15
17	7	18	-.55	.56	.85	-.5	.82	-.4	.59	.49	77.8	73.0	S17
19	6	18	-.86	.57	.85	-.5	.72	-.6	.60	.48	77.8	74.1	S19
20	5	18	-1.21	.60	1.41	1.3	1.82	1.5	.14	.47	66.7	77.3	S20
21	5	18	-1.21	.60	1.18	.7	1.13	.4	.36	.47	66.7	77.3	S21
MEAN	11.0	18.0	.85	.69	.99	.0	1.09	.1			80.3	77.8	
P.SD	4.2	.0	1.60	.29	.19	.7	.73	1.0			9.4	7.1	

Table 3.5 indicates the item statistics as generated by Rasch analysis. The measure statistic highlighted in red showed the level of difficulty of the items with negative values indicating difficult items. The overall measure was 0.00, which indicated that the test in general was neither difficult nor easy. Most of the z-standardised scores highlighted in blue were between -2 and +2, which indicated the items measure a single construct – physical science CK. The number highlighted in green is known as separation value and it indicates the range of difficulty between the items; the larger the number the wider the range. For CK, the separation value was1.67, which indicated that the range of difficulty between the items was small to moderate.

Table 3.5: Item measure statistics for content knowledge

TABLE 13.1 CK - Achievement test ZOU970WS.TXT Aug 2 2017 18:26
INPUT: 21 Person 18 Item REPORTED: 21 Person 18 Item 2 CATS MINISTEP 4.0.0

Person: REAL SEP.: 1.84 REL.: .77 ... Item: REAL SEP.: 1.67 REL.: .74

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
3	7	21	1.82	.58	.41	-2.4	.30	-1.7	.87	.61	100.0	79.4	I0003
14	8	21	1.49	.57	.85	-.4	.77	-.4	.68	.61	85.0	78.5	I0014
16	8	21	1.49	.57	.88	-.3	1.20	.6	.63	.61	85.0	78.5	I0016
13	9	21	1.18	.55	1.11	.5	1.22	.7	.54	.60	75.0	77.1	I0013
18	9	21	1.18	.55	1.12	.5	1.05	.3	.55	.60	75.0	77.1	I0018
8	11	21	.59	.54	1.47	1.6	1.69	1.7	.33	.57	60.0	75.3	I0008
12	11	21	.59	.54	.90	-.3	.92	-.1	.61	.57	80.0	75.3	I0012
17	11	21	.59	.54	1.20	.8	1.34	1.0	.46	.57	70.0	75.3	I0017
11	12	21	.31	.53	.93	-.2	1.11	.4	.56	.55	85.0	74.7	I0011
10	13	21	.02	.54	.67	-1.5	.53	-1.1	.69	.52	85.0	73.7	I0010
5	14	21	-.27	.54	.86	-.6	.72	-.4	.57	.49	85.0	72.9	I0005
7	15	21	-.56	.55	.79	-.9	.57	-.7	.58	.46	75.0	73.8	I0007
1	16	21	-.88	.57	1.53	2.0	2.02	1.3	.10	.42	65.0	76.6	I0001
4	16	21	-.88	.57	.89	-.4	.74	-.2	.48	.42	85.0	76.6	I0004
9	16	21	-.88	.57	1.11	.5	.99	.2	.37	.42	75.0	76.6	I0009
6	17	21	-1.23	.61	.68	-1.1	.42	-.6	.55	.38	80.0	79.9	I0006
15	18	21	-1.63	.67	.96	.0	2.24	1.2	.25	.33	85.0	84.9	I0015
2	20	21	-2.95	1.05	1.14	.5	1.85	1.0	.03	.19	95.0	95.0	I0002
MEAN	12.8	21.0	.00	.59	.97	-.1	1.09	.2			80.3	77.8	
P.SD	3.7	.0	1.23	.12	.27	1.0	.54	.9			9.5	5.0	

Rasch analysis also calculates both item and persons' reliability indices. Persons' reliability refers to the probability of the sample obtaining similar results if a different test measuring the same construct is administered while item reliability refers to the probability that a similar sample will produce similar results. Similar to some reliability tests, numbers over 0.7 to 1 are considered reliable. As indicated in Table 3.6, the persons and items reliability highlighted in orange were 0.77 and 0.74 respectively, which meant that the instrument was sufficiently reliable.

Table 3.6: Summary of measure statistics for content knowledge

CK - Achievement test

Person	21 INPUT		21 MEASURED		INFIT		OUTFIT	
	TOTAL	COUNT	MEASURE	REALSE	IMNSQ	ZSTD	OMNSQ	ZSTD
MEAN	11.0	18.0	.85	.71	.99	.0	1.09	.1
P.SD	4.2	.0	1.60	.29	.19	.7	.73	1.0
REAL RMSE	.76	TRUE SD	1.41	SEPARATION	1.84	Person RELIABILITY		.77
Item	**18 INPUT**		**18 MEASURED**		**INFIT**		**OUTFIT**	
	TOTAL	COUNT	MEASURE	REALSE	IMNSQ	ZSTD	OMNSQ	ZSTD
MEAN	12.8	21.0	.00	.62	.97	-.1	1.09	.2
P.SD	3.7	.0	1.23	.13	.27	1.0	.54	.9
REAL RMSE	.63	TRUE SD	1.06	SEPARATION	1.67	Item RELIABILITY		.74

3.8.3.2 Rasch analysis for PCK items

Table 3.7 indicates the persons-measure statistic as generated by Rasch analysis for PCK items. The measure statistic highlighted in red showed that most of the respondents found the test to be manageable but seven respondents, as indicated by the negative numbers found the test to be difficult. This may be attributed to the fact that there was no straightforward right and wrong answer with the PCK items. Respondents therefore may have found it difficult to identify the best approach in the options provided. All the standard z-scores highlighted in blue were between -2 and +2, which was an indication that the instrument was statistically valid.

Table 3.7: Person measure statistics for pedagogical content knowledge

TABLE 17.1 PCK - Achievement test ZOU180WS.TXT Aug 2 2017 19:21
INPUT: 21 Person 6 Item REPORTED: 21 Person 6 Item 2 CATS MINISTEP 4.0.0

Person: REAL SEP.: 1.38 REL.: .66 ... Item: REAL SEP.: 3.15 REL.: .91

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
1	6	6	4.72	1.92	MAXIMUM MEASURE				.00	.00	100.0	100.0	S01
3	6	6	4.72	1.92	MAXIMUM MEASURE				.00	.00	100.0	100.0	S03
6	5	6	3.14	1.26	1.03	.2	.46	.0	.44	.43	83.3	82.9	S06
7	5	6	3.14	1.26	1.03	.2	.46	.0	.44	.43	83.3	82.9	S07
9	5	6	3.14	1.26	.67	-.5	.31	-.2	.51	.43	83.3	82.9	S09
10	5	6	3.14	1.26	1.03	.2	.46	.0	.44	.43	83.3	82.9	S10
15	5	6	3.14	1.26	1.81	1.5	1.38	.7	.21	.43	83.3	82.9	S15
16	5	6	3.14	1.26	.67	-.5	.31	-.2	.51	.43	83.3	82.9	S16
18	5	6	3.14	1.26	.67	-.5	.31	-.2	.51	.43	83.3	82.9	S18
4	4	6	1.71	1.19	2.28	1.7	4.27	1.8	.22	.62	66.7	83.5	S04
8	3	6	.27	1.23	.27	-1.2	.18	-.5	.86	.72	100.0	86.1	S08
13	3	6	.27	1.23	1.70	1.0	.99	.5	.61	.72	66.7	86.1	S13
14	3	6	.27	1.23	.27	-1.2	.18	-.5	.86	.72	100.0	86.1	S14
19	3	6	.27	1.23	.27	-1.2	.18	-.5	.86	.72	100.0	86.1	S19
17	2	6	-1.25	1.27	1.07	.3	.47	.0	.73	.72	66.7	83.4	S17
20	2	6	-1.25	1.27	.61	-.6	.28	-.3	.81	.72	100.0	83.4	S20
2	1	6	-3.35	1.70	.17	-.7	.08	-.7	.79	.67	100.0	93.2	S02
5	1	6	-3.35	1.70	.17	-.7	.08	-.7	.79	.67	100.0	93.2	S05
11	1	6	-3.35	1.70	.17	-.7	.08	-.7	.79	.67	100.0	93.2	S11
12	1	6	-3.35	1.70	4.09	1.9	1.89	1.0	.23	.67	66.7	93.2	S12
21	1	6	-3.35	1.70	.17	-.7	.08	-.7	.79	.67	100.0	93.2	S21
MEAN	3.4	6.0	.71	1.42	.95	-.1	.65	-.1			86.8	86.4	
P.SD	1.8	.0	2.81	.25	.95	.9	.97	.6			12.8	4.3	

The overall measure of the PCK items as indicated in Table 3.8 was 0.00, which indicated that, similar to the CK test, the PCK test was neither difficult nor easy. Most of the z-standardised scores highlighted in blue were between -2 and +2, which indicated the items measure a single construct – physical science PCK. The separation value for PCK items was 3.15, which indicated that the range of difficulty between the items was moderately large.

Table 3.8: Item measure statistics for pedagogical content knowledge

TABLE 13.1 PCK - Achievement test ZOU180WS.TXT Aug 2 2017 19:21
INPUT: 21 Person 6 Item REPORTED: 21 Person 6 Item 2 CATS MINISTEP 4.0.0

Person: REAL SEP.: 1.38 REL.: .66 ... Item: REAL SEP.: 3.15 REL.: .91

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
6	6	21	3.09	.68	.83	-.7	.39	-.1	.67	.63	84.2	79.6	I0006
3	7	21	2.64	.67	1.03	.2	.54	.1	.67	.67	78.9	82.5	I0003
5	10	21	1.24	.70	.88	-.1	.64	.1	.79	.76	89.5	86.3	I0005
4	14	21	-.82	.75	.74	-.5	.36	-.4	.82	.76	89.5	87.5	I0004
2	15	21	-1.39	.77	1.39	.9	1.72	.9	.65	.74	84.2	87.9	I0002
1	20	21	-4.77	1.07	.92	.1	.27	-.3	.32	.32	94.7	94.4	I0001
MEAN	12.0	21.0	.00	.77	.96	.0	.65	.0			86.8	86.4	
P.SD	4.9	.0	2.69	.14	.21	.5	.49	.4			5.0	4.6	

As indicated in Table 3.9, the persons and items reliability highlighted in orange were 0.66 and 0.91, respectively, which meant that the PCK items could be considered to be sufficiently reliable.

Table 3.9: Summary of measure statistics for pedagogical content knowledge

PCK - Achievement test

Person	21 INPUT TOTAL	COUNT	21 MEASURED MEASURE	REALSE		INFIT IMNSQ	INFIT ZSTD	OUTFIT OMNSQ	OUTFIT ZSTD
MEAN	3.4	6.0	.71	1.57		.95	-.1	.65	-.1
P.SD	1.8	.0	2.81	.48		.95	.9	.97	.6
REAL RMSE	1.65	TRUE SD	2.27	SEPARATION	1.38	Person RELIABILITY			.66
Item	**6 INPUT TOTAL**	**COUNT**	**6 MEASURED MEASURE**	**REALSE**		**INFIT IMNSQ**	**INFIT ZSTD**	**OUTFIT OMNSQ**	**OUTFIT ZSTD**
MEAN	12.0	21.0	.00	.80		.96	.0	.65	.0
P.SD	4.9	.0	2.69	.14		.21	.5	.49	.4
REAL RMSE	.81	TRUE SD	2.56	SEPARATION	3.15	Item RELIABILITY			.91

In summary, Rasch analysis is a powerful tool for elucidating the structure of responses to items. The software used (MINISTEP) is versatile and provides numerous ways to consider the validity and reliability of the items. Since the present study's mandate is not to validate the achievement test comprehensively, the statistics discussed above make a good case in terms of validity and reliability for both sections of the achievement test.

3.10 Data coding

Normally, the use of computer software such as SPSS requires data to be converted into numbers for ease of interpretation. This process is known as data coding and it entails the allocation of codes to responses, production of a codebook and the validation of the codes developed (McMillan & Schumacher, 2014).

The achievement test was coded using the two responses, which were 1 for correct and 0 for incorrect response.

Most of the Likert scale items for teacher beliefs were coded using the six responses, which were 1 – strongly disagree, 2 – disagree,3 – slightly disagree, 4 – slightly agree, 5 – agree, 6 – strongly agree. Only one Likert-type scale was coded 1 – Not at all, 2 – A minor extent, 3 – A modest extent and 4 – A major extent.

The OTL scales had yes/no items and the code used was 1 for Yes and 0 for No. The Likert-type scales were coded using the 4 responses, which were 1 – Never, 2 – Rarely, 3 – Occasionally and 4 – Often. Other Likert-scale items were coded 1 – Disagree, 2 – Slightly disagree, 3 – Slightly agree and 4 – Agree.

3.11 Data cleaning and handling of missing data

It is common for respondents not to fill the survey in its entirety and therefore the handling of missing data is an important aspect of quantitative analysis (Cohen *et al.*, 2013). Improper handling of missing data may lead to distortions in the data, because the researcher is left to assume that the missing values differ in significant ways from the available values (Garson, 2015). Simply put, the remaining data may lead to biased and invalid conclusions. In some instances, respondents who do not satisfy the criteria of the sampling framework complete the questionnaire and the inclusion of their data in analysis will cause distortions in the data. The next section therefore gives a brief account of the handling of missing values and data cleaning in general.

In total, 131 questionnaires were filled and returned. The first step was to ensure that the respondents were final-year BEd candidates. After scanning through the questionnaires, it was discovered that 12 questionnaires had been filled by Post Graduate Certificate in Education (PGCE) candidates and therefore their data were not included in the final analysis.

The second step was to look for questionnaires where the respondents did not complete three or more pages. There were seven such cases and their data were excluded in the analysis.

The third step was to analyse the nature of the missing values in the remaining 112 questionnaires using Little's Missing Completely at Random (MCAR) test (Little & Rubin, 1987). MCAR exists when the missing values tend to be distributed across all the cases, i.e. missingness in a certain variable is independent of any other observed or unobserved variables (Garson, 2015). MCAR is determined by separating cases with complete values from those with missing values and using a t-test of the mean differences of important variables to determine if the two groups do not differ significantly on any of the variables in the envisaged model (Little & Rubin, 1987). For the present study, Little's MCAR test was done using SPSS and the results indicated that the MCAR was not significant (Chi-square = 792.42, DF = 815, $p = 0.708$). This meant that the missingness of the values was completely random and the missing values will not significantly ($p = 0.708$) affect the findings after analysis. There was therefore no need to delete any cases and the imputation of the missing values would not significantly affect the validity of the findings.

The fourth step was the imputation of the missing values to satisfy the conditions of some statistical tests. If the respondent did not choose an answer in the achievement test, it was coded as incorrect. The arithmetic mean was used for imputation of missing values for all the Likert scale items using SPSS (see questionnaire). Finally, a negative response (no) was applied for the yes/no items with missing values. The missing data accounted for less than 1% of the data.

3.12 Data analysis

Data were analysed using various statistical tests for the generation of relevant data/results that might help answer the research questions. Data were subjected to descriptive statistics and in some cases, distributional properties of the data were determined to enable the selection of appropriate statistical tests. Descriptive methods were used because they reduce the data and provide a single number, which represents the stance of a sample on a particular issue. Descriptive statistics therefore provide a summary of indicators, which can be compared across groups or units (Johnson & Christensen, 2012).

Response frequencies were determined to provide a broad view of the respondents from each university and the view of the entire sample. Since Likert scales were used to collect data, means were calculated to indicate a single value that could represent the items in a scale. In some instances, means and standard deviations were calculated to indicate patterns in the data. Although this is so, I acknowledge that statistically speaking, Likert-scale data are not continuous but if the data are normally distributed, parametric statistics can be applied to the data (Sullivan & Artino, 2013). As there were some items that were negatively phrased in the questionnaire, I first transformed and recoded the responses using SPSS before any type of statistical analysis was applied to the data.

The mean score of the achievement test was calculated for each respondent and the means for the respective universities were calculated for comparative purposes. The means of the entire sample were also calculated.

Correlations are often used in statistics to describe the degree of relationships between two variables. A correlation coefficient approaching 0 indicates that there is little or no relationship between the variables in question (Pallant, 2001). A correlation coefficient of less than 0.3 is considered weak and a correlation coefficient between 0.3-0.49 is considered moderate, while a coefficient of over 0.5 is indicative of strong associations between the variables (Pallant, 2001). The OTL variables were correlated with PSTs' knowledge and beliefs to determine if there were negative or positive relationships. For example, the six OTL variables were each correlated to the achievement scores to determine whether they exhibited any relationships, be it positive or negative. The correlations in the present study were also tested for statistical significance, i.e. how likely it was that the correlations were due to chance associated with sampling error (Cohen *et al.*, 2013). The correlations were determined using SPSS 24.

The present study used regression analysis, a procedure utilised to estimate the nature of the relationships among variables. Regression analysis includes techniques that analyse, model and describe the relationship between the dependent and the independent variables (McMillan & Schumacher, 2014). The strength of regression analysis lies in its ability to predict variables that influence the dependent variables (Johnson & Christensen, 2012). This allowed for the determination of the effect of the OTL variables on the PSTs knowledge and beliefs variable, while other OTL variables were kept constant. The present study used this technique to determine the OTL that affect PSTs' knowledge and beliefs significantly. This technique allowed for the determination of OTL that were predictors of multiple knowledge and beliefs bundles variables.

The programme designs from the four universities including the structure of the courses offered were collected and used for accounting for some of the findings.

3.13 Ethical considerations

I informed the potential respondents of the purpose, risks, procedures and benefits of the study (Cohen *et al.*, 2013). I further explained the processes that were followed when conducting the study to ensure that the PSTs were comfortable with the processes. The respondents in this study were requested to fill in consent if they were willing to participate.

I considered that no one should be forced or coerced into participating (McMillan & Schumacher, 2014). Respondents in this study were informed that their participation in the study was voluntary and they had the option to withdraw from participating without any ramifications or consequences.

I requested the respondents not to write their names on the test or the questionnaire to ensure that the respondents remained anonymous even to the researcher (Johnson & Christensen, 2010). Furthermore, because of the nature of the research study, all the participating universities made it a condition that I should not reveal their identities in any of the reports emanating from the research study.

3.14 Delimitations and limitations

This study focused on physical science PSTs who were in the last year (4^{th} year) of their training at South African TEIs. The study also focused on PSTs enrolled for the FET phase programme. PSTs who were doing their degree through the PGCE route were not considered for the study. The assumption was that they have gone through more rigorous content training than those that went through a four-year Bachelor of Education (BEd) qualification. The result of this was that the two sets of PSTs did not experience similar OTL, even if they were at the same institution.

This study in no way attempted to establish causality, but it only attempted to assess the relative strength of the relationships between the variables (OTL, teacher knowledge and beliefs) in question. The designs and methodologies used in this study did not allow causality to be established.

The other challenge is the low number of PSTs who enrol for a teaching qualification through the BEd route at FET level. While the number of respondents in this study was sufficient for a power of 0.8 and an alpha of 0.05 with medium effect size, the number of respondents for the same power but with small effect size was approximately 700 (Wilson-VanVoorhis & Morgan, 2007). This was more than the total population of BEd final-year physical science PSTs in the country and therefore it was possible that if the effect of the independent variables was small enough, it would not be detected by the statistical tests.

3.15 Conclusion

It is vital to have a clear and an achievable plan when conducting investigations, but even so, challenges are encountered at times. It is always important for researchers to guard and protect the integrity of the research process. This chapter presented the ideas I drew on including the paradigm, approach and designs that guided the investigation. The chapter further described the methodology which was followed to sample, contact, request permission and ultimately to collect data at various universities. The construction of different sections of the questionnaire were also discussed and the measures to ensure the reliability and validity of the items were described. Analysis of the collected data was discussed in this chapter and the chapter concluded by discussing ethical issues and limitations of the present study. The following chapter is a presentation of the collected data and its analysis.

Chapter 4

Data analysis and discussion

4.1 Introduction

This chapter presents the collected data and its subsequent analysis. The findings are discussed in this chapter and the discussions are supported by relevant literature. A self-reported questionnaire, which included an achievement test, PSTs' beliefs and the opportunities to learn, was used to collect the data. The chapter begins by presenting demographic information of the respondents. Descriptive statistics of the data, which include comparisons of the constructs (PSTs' knowledge, beliefs and OTL) between teacher education programmes, are also presented. Correlation coefficients between the dependent variables (PSTs' knowledge and beliefs) and the independent variables (OTL) are determined to assess the strength of associations between them. Finally, regression analysis is done to determine which items account for the variance observed in the dependent variables, i.e. which items are good predictors of changes in the dependent variables. All the statistical tests were done using SPSS 24.

Data are presented in two phases. The first phase presents data from individual universities to determine similarities and differences between the universities data and the second phase presents aggregated mean data from the four universities. The findings are grouped in terms of the research question of the study.

4.2 Demographic information

Table 4.1 contains the demographic information of the respondents and it indicates that 54 (48.2%) of the respondents are female, while 58 (51.8%) are male, meaning that the respondents do not differ significantly in terms of gender distribution. In terms of age, 59 (52.7%) respondents are under 25 years; 37 (33.0%) are between 25 and 29 years; 15

(13.4%) are between 30 and 39 years; while only one (0.9%) respondent is between 40 and 49 years. Most of the respondents 102 (91.1%) indicate that they are unemployed and of the employed 10 (8.9%) respondents, 8 (7.1%) have been employed for under a year, while 2 (1.8) have been employed for a period between 5 and 9 years. All the respondents indicate that they do not hold any post-school qualifications.

Table 4.1: Biographical details of the respondents

Gender of respondents		**Frequency**	**Percentage (%)**
	Female	54	48.2
	Male	58	51.8
	Total	**112**	**100**
Age of respondents		**Frequency**	**Percentage (%)**
	Under 25 years	59	52.7
	25 to 29 Years	37	33.0
	30 to 39 Years	15	13.3
	40 to 49 Years	1	0.9
	Total	**112**	**100.0**
Employment status		**Frequency**	**Percentage (%)**
	Employed	10	8.9
	Not employed	102	91.1
Length of employment		**Frequency**	**Percentage (%)**
	Not employed	102	91.1
	Under a year	8	7.1
	4 to 9 Years	2	1.8
	Total	**112**	**100.0**
Highest qualifications		**Frequency**	**Percentage (%)**
	No Qualification	**112**	**100.0**

4.3 Knowledge scores

This section presents content and pedagogical content knowledge data of the respondents from U1, U2, U3 and U4 as individual samples.

4.3.1 Mean knowledge scores for the universities data

The section below presents the individual universities mean CK and PCK scores.

4.3.1.1 Content Knowledge (CK) data

Table 4.2 presents CK data of the respondents. CK was assessed using multiple-choice items, which were based on the topics as described in the CAPS documents. The correct response is coded 1 and an incorrect response is coded 0. There are 18 items (appendix 1) in the CK section. Two items are described below to provide a sense of the type of items in the CK part of the questionnaire.

Item 13 addressed two topics in the chemistry section of the physical science curriculum. The item was designed to test PSTs' understanding of phase changes and, in a way, chemical reactions as well. The item was phrased in the following manner:

Atlegang is observing boiling water in a glass beaker. She deduces that the bubbles rising from the bottom of the beaker are air bubbles. Does Atlegang fully understand the concept of phase change?

Four choices were provided and 48 (43.0%) respondents chose the correct option (Option d) which said, “No, the bubbles rising are caused by water vapour.” The second-highest number of respondents, which was 36 (32.1%), chose option b, which stated, “No, the bubbles rising are caused by the breaking down of water into hydrogen and oxygen.”

Item 1 addressed gravity and it was phrased in the following manner:

Neil Armstrong is standing on the surface of the moon holding a cricket ball 2 metres above its surface. The teacher asks what will happen to the ball if it is released. Which explanation is correct?

Similar to item 13, four choices were provided. 57 (51.0%) respondents chose the correct option, which stated, "The gravity of the moon will pull the cricket ball towards its surface with a gravitational acceleration, which is less than that of the earth." 25 (22.3%) respondents chose Option b, which stated, "The ball will continue to float because there is no gravity on the moon."

Table 4.2: CK mean scores of universities

	CK	
University	**Mean (%)**	**Standard deviation**
U1	46.6	16.9
U2	71.5	12.6
U3	41.9	22.8
U4	43.0	17.3
Aggregate Mean	52.0	

The CK scores show that the percentages of correct responses differ across the four universities. CK achievement scores of universities 1, 2, 3 and 4 in percentages are U1: M = 46.6, SD =16.9; U2: M = 71.6, SD = 12.6; U3: M = 41.9, SD = 22.8; U4: M = 43.0, SD = 17.3. Data indicate that respondents from U3 (41.9%) have the least number of correct responses, followed by U4 (43.0%) and U1 (46.6%). However, U2 (71.5%) has the highest number of correct responses for CK. Data also reveal that only U2 scores are above the aggregated mean score (M = 52.0%).

4.3.1.2 Pedagogical Content Knowledge (PCK)

Table 4.3 presents data on the PCK of the respondents. PCK was assessed using multiple-choice items, which were based on the teaching strategies and learner misconceptions aspects of PCK. Similar to the CK items, the most desirable response was coded 1 and other responses were coded 0. The PCK variable consisted of 6 items (appendix 1) in total. Two items are described below to provide a sense of the type of items in the PCK part of the questionnaire.

Item 8 addressed teaching strategies and it was phrased in the following manner:

A practical way of introducing forces (Newton's second law) for learners is to have a learner pull a trolley with little friction while another sits on it. Which one of the following approaches is best suited for fostering inquiry in learners?

The item was based on Bruner's and Piaget's ideas on discovery learning, which emphasize that best way to learn is through self-discovery inquiry.

A fair number of respondents 64 (57.1%) chose the best option, which stated, "You first let the learners pull the trolley at constant speed, then guide the learner to the law by asking questions and affording them the opportunity to deduce their own laws before explaining the correct law." The second highest group of respondents, 22 (19.6%), chose the option that stated, "You first define acceleration and link it to Newton's second law by using examples relating acceleration to net force and then you let learners experience it by playing with a trolley."

Item 17 addressed the manner in which the teacher approached correcting misconceptions. The item was phrased in the following manner:

Learners worked on a kinetics experiment and collected data in groups. In a discussion with the whole class, one group's data seems not to be consistent with data from the whole class. How would you handle this situation?

This item is based Piaget's concept of assimilation which, in a way, emphasizes the importance of learners confronting their misconceptions.

A fair number of respondents 62 (55.4%) chose the best option, which stated, “Ask the learners to find a way of resolving the issue by having the group with the inconsistent data explain how they gathered the data.” The second highest group of respondents, 21 (18.8%), chose the option that stated, “Ask the learners to read through the textbook to try and identify what could have gone wrong with the inconsistent data.”

Table 4.3: PCK mean scores of universities

	PCK	
University	**Mean (%)**	**Standard deviation**
U1	56.9	26.0
U2	71.7	19.3
U3	53.1	27.4
U4	52.1	21.0
Aggregate Mean	59.1	

The PCK scores from Table 4.3 show that the percentages of correct responses differ across the four universities. PCK achievement scores of universities 1, 2, 3 and 4 in percentages are U1: M = 56.9, SD = 26.0; U2: M = 71.7, SD = 19.3; U3: M = 53.1, SD = 27.4; U4: M = 52.1, SD = 21.0. The PCK scores reveal that U4 (52.1%) respondents have the least number of correct responses followed by U3 (53.1%) and U1 (56.9%). However, U2 (71.7%) respondents have the highest frequency of correct responses for PCK. Data also reveal that only U2 score is above the aggregated mean score for PCK (M = 59.1%).

4.3.2 ANOVA and post-hoc tests for the knowledge scores

The data below provide statistics on the ANOVA and the post-hoc tests for CK and PCK mean scores. ANOVA tests are normally done to determine if there are statistically significant variations in the mean scores of different groups on the same variable. In the context of the present study, ANOVA is used to determine if there are variations in the participating universities mean scores on the variables measured. Levene’s tests check if homogeneity of variances is assumed and post hoc tests reveal the statistical differences between the universities mean scores.

4.3.2.1 ANOVA test for CK mean scores

Table 4.4 presents ANOVA test statistics for CK and it indicates that the universities' mean CK scores are not statistically equivalent (F = 22.58, p = 0.00).

Table 4.4 ANOVA test for CK mean scores

		Sum of Squares	df	Mean Square	F	Sig.
CK	Between Groups	1.825	3	0.608	22.576	0.000
	Within Groups	2.910	108	0.027		
	Total	4.735	111			

Levene's test of homogeneity of variances in Table 4.5 indicates that equal variances are not assumed (*F*(3,108) = 3.11, p = 0.03) for the CK mean scores.

Table 4.5 Levene's test of homogeneity of variances of the CK mean scores

	Levene Statistic	df1	df2	Sig.
CK	3.11	3	108	0.029

Table 4.6 presents the Games-Howell post-hoc test. It indicates that U2 (71.5%) scores are not statistically significantly equivalent to U1 (46.6%), U3 (41.9%) and U4(43.0%) scores. Furthermore, the post-hoc test revealed that U1, U3 and U4 mean scores are statistically equivalent.

Table 4.6: ANOVA post-hoc tests for the CK mean scores

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
CK	U1	U2	-0.25*	0.00
		U3	0.04	0.91
		U4	0.03	0.88
	U2	U1	0.25*	0.00
		U3	0.29*	0.00
		U4	0.28*	0.00
	U3	U1	-0.04	0.91
		U2	-0.29*	0.00
		U4	-0.01	0.99
	U4	U1	-0.03	0.88
		U2	-0.28*	0.00
		U3	0.01	0.99

4.3.2.1 ANOVA test for PCK mean scores

Table 4.7 presents ANOVA test statistics for PCK. It indicates that the universities' mean PCK scores are not statistically equivalent (F = 5.01, p = 0.00).

Table 4.7 ANOVA test for the PCK mean scores

		Sum of Squares	df	Mean Square	F	Sig.
PCK	Between Groups	0.778	3	0.259	5.010	0.003
	Within Groups	5.587	108	0.052		
	Total	6.365	111			

Levene's test of homogeneity of variances in Table 4.8 indicates that equal variances are assumed ($F(3,108) = 2.08$, p = 0.11) for the PCK mean scores.

Table 4.8 Levene's test of homogeneity of variances of the PCK mean scores

	Levene Statistic	df1	df2	Sig.
PCK	2.08	3	108	0.106

Table 4.9 presents the Tukey's post-hoc test and it indicates that U2 (71.7%) and U1 (56.9%) mean score are in one subset and U1 (56.9%), U3 (53.1%) and U4 (52.1%) are in another. Furthermore, the post-hoc test reveals that U2 scores are not statistically significantly equivalent to U3 and U4 scores.

Table 4.9: ANOVA post-hoc tests for the PCK mean scores

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
PCK**	U1	U2	-0.14	0.09
		U3	0.04	0.93
		U4	0.05	0.80
	U2	U1	0.14	0.09
		U3	0.18*	0.04
		U4	0.19*	0.00
	U3	U1	-0.04	0.93
		U2	-0.18*	0.04
		U4	0.00	0.99
	U4	U1	-0.05	0.80
		U2	-0.19*	0.00
		U3	-0.00	0.99

4.3.3 Summary of the knowledge scores

The data indicates that with the exception of U2, the other universities' mean scores on CK are below 50%. This indicates that there may be gaps in the PSTs CK from the said universities. The situation is quite different for PCK where all the universities' scores are above 50%, suggesting that the PSTs have higher PCK than CK. Similar to the CK results, only U2 scores are above the aggregated mean score. Interestingly, U2 respondents have the highest number of correct responses for both CK and PCK.

4.4 Pre-service teachers' beliefs

PSTs' beliefs were measured using Likert-scale items. The measured construct consisted of items on beliefs about the nature of science (BLF1), learning science (BLF2), science achievement (BLF3), preparedness for teaching physical science (BLF4) and programme effectiveness (BLF5). The Likert-scale items for PSTs' beliefs were coded using the 6 responses which were 1 - *strongly disagree*, 2 - *disagree*, 3 - *slightly disagree*, 4 - *slightly agree*, 5 - *agree*, 6 - *strongly agree*. Only the Likert scale on teacher preparedness for teaching physical science (BLF4) was coded 1 - *Not at all*, 2 - *A minor extent*, 3 - *A modest extent* and 4 - *A major extent*.

To ensure the instruments' sensitivity, some items were negatively worded and in some cases, the respondents were expected to choose negative responses (options with disagree) as desirable beliefs. The items were therefore recoded so that the desirable beliefs were assigned 4, 5 and 6, while the undesirable beliefs were assigned 3, 2 and 1. It was necessary to recode the items because the data were used for correlations and regression analysis at a later stage. Similar to the TEDS-M study reasoning, only respondents who chose the *agree* and *strongly agree* (5 and 6) options were considered to be in agreement with the item and the rest, including *slightly agree* (4), were considered as not being in agreement with the item. For the teacher-preparedness Likert scale, only respondents who chose option 4 were considered to be in agreement with the item. The descriptions above are used in the data presentations that follow.

4.4.1 Mean belief bundles scores for the universities data

The section below presents the individual universities' belief bundles mean scores.

4.4.1.1 Beliefs about the nature of science (BLF1)

Table 4.10 presents PSTs' frequencies of desirable beliefs about the nature of science. The percentages of respondents who are in agreement with the desirable beliefs for U1, U2, U3 and U4 are 8.3, 97.0, 31.3 and 12.8% respectively. The average percentage of desirable beliefs about the nature of science for the universities is 39.3%.

Table 4.10: Belief about the nature of science mean scores of universities

University	BLF1 (%)
U1	8.3
U2	97.0
U3	31.3
U4	12.8
Ave	39.3

4.4.1.2 PSTs' beliefs about learning science (BLF2)

Table 4.11 presents PSTs' frequencies of desirable beliefs about learning science. The percentages of respondents who are in agreement with the desirable beliefs for U1, U2, U3 and U4 are 33.3, 97.0, 56.3 and 53.8% respectively. The average percentage of desirable beliefs about learning science for the universities is 62.5%.

Table 4.11: Belief about the learning science mean scores of universities

University	BLF2 (%)
U1	33.3
U2	97.0
U3	56.3
U4	53.8
Ave	62.5

4.4.1.3 PSTs' beliefs about science achievement (BLF3)

Table 4.12 presents PSTs' frequencies of desirable beliefs about science achievement. The percentages of respondents who are in agreement with the desirable beliefs for U1, U2, U3 and U4 are 62.5, 100.0, 43.8 and 46.2% respectively. The mean percentage of desirable beliefs about science achievement for the universities is 65.2%.

Table 4.12: Belief about science achievement mean scores of universities

University	**BLF3 (%)**
U1	62.5
U2	100
U3	43.8
U4	46.2
Ave	65.2

4.4.1.4 PSTs' beliefs about preparedness for teaching physical science (BLF4)

Table 4.13 presents PSTs' frequencies of desirable beliefs about preparedness for teaching physical science. The percentages of respondents who are in agreement with the desirable beliefs for U1, U2, U3 and U4 are 33.3, 66.7, 75.0 and 51.3% respectively. The average percentage of desirable beliefs about preparedness for teaching physical science for the universities is 55.4%.

Table 4.13: Belief about preparedness for teaching mean scores of universities

University	**BLF4 (%)**
U1	33.3
U2	66.7
U3	75.0
U4	51.3
Ave	55.4

4.4.1.5 PSTs' beliefs about programme effectiveness (BLF5)

Table 4.14 presents PSTs' frequencies of desirable beliefs about programme effectiveness. The percentages of respondents who are in agreement with the desirable beliefs for U1, U2, U3 and U4 are 37.5, 100.0, 93.8 and 66.7% respectively. The mean percentage of desirable beliefs about programme effectiveness for the universities is 73.2%.

Table 4.14: Belief about programme effectiveness mean scores of universities

University	BLF5 (%)
U1	37.5
U2	100
U3	93.8
U4	66.7
Ave	73.2

4.4.2 ANOVA and post-hoc tests for the belief bundles mean scores

The statistics below provides data on the ANOVA and the post-hoc tests for belief bundles' mean scores.

4.4.2.1 ANOVA test for beliefs about the nature of science (BLF1)

Table 4.15 presents ANOVA test statistics for beliefs about the nature of science and it indicates that the universities' beliefs about the nature of science mean scores are not significantly equivalent (F = 70.13, p = 0.00).

Table 4.15: ANOVA test for the beliefs about the nature of science mean scores

		Sum of Squares	df	Mean Square	F	Sig.
BLF1	Between Groups	60.351	3	20.117	70.123	0.000
	Within Groups	30.984	108	0.287		
	Total	91.335	111			

Levene's test of homogeneity of variances in Table 4.16 indicates that equal variances are not assumed for beliefs about the nature of science $F(3,108) = 3.19$, p = 0.026.

Table 4.16: Levene's test for homogeneity of variances of the beliefs about the nature of science mean scores

	Levene Statistic	df1	df2	Sig.
BLF1	3.19	3	108	0.026

Table 4.17 presents the Games-Howell post-hoc test. It indicates that U2 (97.0%) scores on beliefs about the nature of science are not statistically significantly equivalent to U1 (8.3%),

U3 (31.3%) and U4 (12.8%) mean scores. Furthermore, the post-hoc test shows that U1, U3 and U4 mean scores are statistically significantly equivalent.

Table 4.17: ANOVA post-hoc tests beliefs about the nature of science mean scores

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
BLF1	U1	U2	-1.67*	0.00
		U3	-0.28	0.63
		U4	-.04	0.97
	U2	U1	1.67*	0.00
		U3	1.39*	0.00
		U4	1.63*	0.00
	U3	U1	0.28	0.63
		U2	-1.39*	0.00
		U4	0.23	0.74
	U4	U1	0.04	0.97
		U2	-1.63*	0.00
		U3	-0.23	0.74

4.4.2.2 ANOVA test for beliefs about learning science (BLF2)

Table 4.18 presents ANOVA test statistics for beliefs about learning science and it indicates that the universities' beliefs about learning science mean scores differ significantly (F = 23.45, p = 0.00).

Table 4.18: ANOVA test for the beliefs about learning science mean scores

		Sum of Squares	df	Mean Square	F	Sig.
BLF2	Between Groups	35.652	3	11.884	23.459	0.000
	Within Groups	54.711	108	0.507		
	Total	90.363	111			

Levene's test of homogeneity of variances in Table 4.19 indicates that equal variances are not assumed for beliefs about learning science $F(3,108) = 6.56$, p = 0.00.

Table 4.19: Levene's test for homogeneity of variances of the beliefs about learning science mean scores

	Levene Statistic	df1	df2	Sig.
BLF2	6.56	3	108	0.000

Table 4.20 presents the Games-Howell post-hoc test and it indicates that U2 (97.0%) scores on beliefs about learning science are not statistically significantly equivalent to U1 (33.3%), U3 (56.3%) and U4 (53.8%) mean scores. Furthermore, the post-hoc test illustrates that U1, U3 and U4 scores are statistically significantly equivalent.

Table 4.20: ANOVA post-hoc tests for beliefs about learning science mean scores

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
BLF2	U1	U2	-1.42*	0.00
		U3	-0.66	0.08
		U4	-0.25	0.55
	U2	U1	1.42*	0.00
		U3	0.75*	0.02
		U4	1.16*	0.00
	U3	U1	0.66	0.08
		U2	-0.72*	0.02
		U4	0.41	0.40
	U4	U1	0.25	0.55
		U2	-1.16*	0.00
		U3	-0.41	0.40

4.4.2.3 ANOVA test for beliefs about science achievement (BLF3)

Table 4.21 presents ANOVA test statistics for beliefs about science achievement and it indicates that the universities' beliefs about science achievement mean scores differ significantly (F = 19.207, p = 0.00).

Table 4.21: ANOVA test for the beliefs about science achievement mean scores

		Sum of Squares	df	Mean Square	F	Sig.
BLF3	Between Groups	44.955	3	14.985	19.207	0.000
	Within Groups	84.259	108	0.780		
	Total	129.214	111			

Levene's test of homogeneity of variances in Table 4.22 indicates that equal variances are not assumed for beliefs about science achievement *F*(3,108) = 10.11, p = 0.00.

Table 4.22: Levene's test for homogeneity of variances of the beliefs about science achievement mean scores

	Levene Statistic	df1	df2	Sig.
BLF3	10.10	3	108	0.000

Table 4.23 presents the Games-Howell post-hoc test and it indicates that U2 (100%) scores on beliefs about science achievement are not statistically significantly equivalent to U1 (62.5%), U3 (43.8%) and U4 (46.2%) mean scores. Furthermore, the post-hoc test reveals that U1, U3 and U4 scores are statistically significantly equivalent.

Table 4.23: ANOVA post-hoc tests for beliefs about science achievement mean scores

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
BLF3	U1	U2	-1.32*	0.00
		U3	0.03	1.00
		U4	0.10	0.98
	U2	U1	1.32*	0.00
		U3	1.36*	0.00
		U4	1.43*	0.00
	U3	U1	-0.03	1.00
		U2	-1.36*	0.00
		U4	0.07	0.99
	U4	U1	-0.10	0.98
		U2	-1.43*	0.00
		U3	-.072	0.99

4.4.2.4 ANOVA test for beliefs about preparedness for teaching physical science (BLF4)

Table 4.24 presents ANOVA test statistics for beliefs about preparedness for teaching physical science and it indicates that the universities' beliefs about preparedness for teaching physical science mean scores differ significantly ($F = 5.23$, $p = 0.00$).

Table 4.24: ANOVA test for the beliefs about preparedness for teaching physical science mean scores

		Sum of Squares	df	Mean Square	F	Sig.
BLF4	Between Groups	8.657	3	2.886	5.226	0.002
	Within Groups	59.634	108	0.552		
	Total	68.292	111			

Levene's test of homogeneity of variances in Table 4.25 indicates that equal variances are not assumed for beliefs about preparedness for teaching physical science *F*(3,108) = 7.74, p = 0.00.

Table 4.25: Levene's test for homogeneity of variances of the beliefs about preparedness for teaching physical science mean scores

	Levene Statistic	**df1**	**df2**	**Sig.**
BLF4	7.74	3	108	0.000

Table 4.26 presents the Games-Howell post-hoc test and indicates that U2 (66.7%) scores on beliefs about preparedness for teaching physical science are not statistically significantly equivalent to U1 (33.3), but statistically significantly equivalent U3 (75.0%) and U4 (51.3%) mean scores. Furthermore, post-hoc tests shows that U3 scores are not statistically significantly equivalent to U1, but statistically significantly equivalent to U2 and U4 scores.

Table 4.26: ANOVA post-hoc tests for beliefs about preparedness for teaching physical science mean scores

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
BLF4	U1	U2	-0.73*	0.00
		U3	-0.72*	0.03
		U4	-0.43	0.23
	U2	U1	0.73*	0.00
		U3	0.00	1.00
		U4	0.29	0.24
	U3	U1	0.72*	0.03
		U2	-0.00	1.00
		U4	0.28	0.53
	U4	U1	0.43	0.23
		U2	-0.29	0.24
		U3	-0.28	0.53

4.4.2.5 ANOVA test for beliefs about programme effectiveness (BLF5)

The ANOVA test in Table 4.27 indicates that the universities' scores for beliefs about programme effectiveness differ significantly (F = 9.432, p = 0.00).

Table 4.27: ANOVA test for the beliefs about programme effectiveness mean scores

		Sum of Squares	df	Mean Square	F	Sig.
BLF5	Between Groups	28.176	3	9.392	9.432	0.000
	Within Groups	107.544	108	0.996		
	Total	135.720	111			

Levene's test of homogeneity of variances in Table 4.28 indicates that equal variances are not assumed for beliefs about programme effectiveness $F(3,108) = 14.15$, p = 0.00.

Table 4.28: Levene's test for homogeneity of variances of the beliefs about programme effectiveness mean scores

	Levene Statistic	df1	df2	Sig.
BLF5	14.15	3	108	0.000

Table 4.29 presents the Games-Howell post-hoc test and it indicates that U2 (100%) scores on beliefs about programme effectiveness are not statistically significantly equivalent to U1(37.5) and U4 (66.7%) but statistically significantly equivalent to U3 (93.8%) scores. Furthermore, the post-hoc test shows that U1 scores are not statistically significantly equivalent to U2 and U3, but statistically significantly equivalent to U4 scores.

Table 4.29: ANOVA post-hoc tests for beliefs about programme effectiveness mean scores

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
BLF5	U1	U2	-1.34*	0.00
		U3	-1.07*	0.01
		U4	-0.56	0.31
	U2	U1	1.34*	0.00
		U3	0.26	0.62
		U4	0.77*	0.00
	U3	U1	1.07*	0.01
		U2	-0.26	0.62
		U4	0.50	0.26
	U4	U1	0.56	0.31
		U2	-0.77*	0.00
		U3	-0.50	0.26

4.4.3 Summary of the beliefs scores

Table 4.10 to 4.14 shows that beliefs about the nature of science (BLF1), learning science (BLF2) and programme effectiveness (BLF5) have similar trends. In all three cases, the respondents that report the lowest frequencies of desirable beliefs are from U1, followed by U4 and U3, while the U2 respondents report the highest frequencies of desirable beliefs. Beliefs about science achievement and preparedness for teaching show no prominent trends. Data reveal that respondents from U2 report the highest frequencies of desirable beliefs in all of the beliefs bundles except for beliefs about preparedness for teaching and U1 respondents report the lowest number of desirable beliefs in all belief bundles, except for beliefs about science achievement. Data also indicate that U2 is the only university whose frequencies of desirable beliefs are above the aggregated mean score of desirable beliefs in all the belief bundles mean scores.

4.5 Opportunity to learn in teacher education programmes

OTL construct consists of OTL tertiary-level physics and chemistry, OTL school physical science, OTL physical science pedagogy, OTL through reflection, OTL through practicum and OTL in a coherent programme (appendix 1). The variables in the opportunity to learn construct are measured using Likert-scale items except the opportunities to learn physics, chemistry and physical science which are assessed using Yes/No options. Some items in the OTL through practicum were recoded because the items were phrased in a negative manner. Frequencies were calculated for opportunities to learn physics, chemistry and physical science and means were calculated for the rest of the OTL variables.

4.5.1 Mean OTL scores for the universities' data

The section below presents the individual universities' mean OTL scores. The numbering of the OTL was kept as in the questionnaire before piloting for tracking purposes and ease of analysis.

4.5.1.1 Opportunity to learn tertiary physics and chemistry (OTL1)

Table 4.30 presents the mean number of tertiary physics and chemistry topics studied for each university. The mean scores of respondents who report that they studied physics and chemistry topics in the questionnaire for U1, U2, U3 and U4 are M = 75.4; M = 93.2; M = 92.8, and M = 80.6 % respectively. Respondents from U2 (93.2%) indicate that they have the OTL the highest number of tertiary physics and chemistry topics, followed by U3 (92.8%) and U4 (80.6%), while respondents from U1 (75.4%) report that they have the OTL the least number of physical science topics. The mean percentage of the number of chemistry and physics topics studied for the universities is 84.9%.

Table 4.30: OTL tertiary physics and chemistry mean scores

University	OTL1
U1	0.75
U2	0.93
U3	0.93
U4	0.81
Mean	0.85

4.5.1.2 Opportunity to learn school-level physical science (OTL2)

Table 4.31 presents the mean number of school-level physical science topics studied for each university. The mean scores of respondents who report that they studied school-level physical science topics in the questionnaire for U1, U2, U3 and U4 are M = 95.0; M = 97.1; M = 92.0; and M = 84.1% respectively. Respondents from U2 (97.1%) indicate that they have the OTL the highest number of school-level physical science topics, followed by U3 (92.0%) and U1 (95.0%), while respondents from U4 (75.4%) report that they have the OTL the least number of physical science topics. The mean percentage of number of school-level physical science topics studied for the universities is 91.4%.

Table 4.31: OTL school-level physical science mean scores

University	OTL2
U1	0.95
U2	0.97
U3	0.92
U4	0.84
Mean	0.91

4.5.1.3 Opportunity to learn physical science pedagogy (OTL6)

Table 4.32 presents the means scores for the OTL physical science pedagogy for each university. The means scores of respondents from U1, U2, U3 and U4 are M = 2.4; M = 3.2; M = 3.3 and M = 2.8, respectively. Respondents from U3 (3.3) indicate that they are afforded the most OTL physical science pedagogy, followed by U2 (3.2) and U4 (2.8), while respondents from U4 (2.4) indicated that they are afforded the least OTL physical science pedagogy. The mean score for OTL physical science pedagogy of all the universities is 2.9.

Table 4.32: OTL physical science pedagogy mean scores of universities

University	OTL6
U1	2.44
U2	3.22
U3	3.28
U4	2.79
Mean	2.91

4.5.1.4 Opportunity to learn through reflection (OTL9)

Table 4.33 presents the means scores for the OTL through reflection for each university. The means scores of respondents from U1, U2, U3 and U4 are M = 2.6, M = 3.1, M = 3.5, and M = 2.8, respectively. Respondents from U3 (3.5) indicate that they are afforded the most OTL through reflection followed by U2 (3.1) and U4 (2.8) while respondents from U4 (2.6) indicate that they are afforded the least OTL through reflection. The mean score of OTL to teach through reflection for the universities is 2.9.

Table 4.33: OTL through reflection mean scores

University	OTL9
U1	2.63
U2	3.12
U3	3.50
U4	2.77
Mean	2.95

4.5.1.5 Opportunity to learn teaching through teaching practice

OTL teaching through teaching practice is divided into two parts. Firstly, the respondents were requested to indicate the amount of time they were in charge of a classroom and the amount of time they spent with their mentors in class during teaching practice. In both cases, the options were less than a quarter of the time (1), between a quarter and half of the time (2), between half and three quarters of the time (3) and over three quarters of the time (4). Secondly, Likert-scale items were used to determine the OTL they experienced with regard to mentoring in schools.

Teaching time (OTL11)

Table 4.34 presents the means scores for the time PSTs are in charge of a class. On average, respondents from U1 and U4 report that they are in charge of a class between a quarter of the time and half the time (U1: M = 2.60 and U4: M = 2.79). Respondents from U2 and U3 report that they present classes between half and three quarters of the time (U2: M = 3.39 and U3: M = 3.47). The mean scores for all the universities indicate that the amount time PSTs spend teaching classes is between a half and three quarters of the time.

Table 4.34: Teaching time mean scores

University	OTL11
U1	2.60
U2	3.39
U3	3.47
U4	2.79
Mean	3.03

Presence of a mentor teacher while teaching (OTL12)

Table 4.35 presents the means scores for the time that the supervising teacher is present when PSTs are in charge of a class. Incidentally, respondents from U1 and U4 report that on average, mentors are present in class between a quarter and half of the time they are in charge of a class (U1: M = 2.75 and U4: M = 2.87). Respondents from U3 and U4 report that mentor teachers are present between half and three quarters of the time they are teaching a class (U2: M = 3.36 and U3: M = 3.50). The mean for all the universities indicates that the amount of time PSTs spend teaching classes with their mentor teachers present is between a quarter and half of the time.

Table 4.35: Presence of a mentor teacher while teaching mean scores

University	OTL12
U1	2.75
U2	3.36
U3	3.50
U4	2.87
Mean	3.08

Opportunity to learn through teaching practice (OTL14)

Table 4.36 presents the means scores for the OTL through teaching practice for each university. The means scores of respondents from U1, U2, U3 and U4 are M = 2.6; M = 3.4; M = 3.5 and M = 2.8, respectively. Respondents from U3 (3.5) indicate that they are afforded the most OTL through teaching practice, followed by U2 (3.4) and U4 (2.8) while respondents from U1 (2.6) indicate that they are afforded the least OTL through teaching practice. The mean score of OTL through teaching practice for the universities is 2.8.

Table 4.36: OTL through teaching practice mean scores

University	OTL14
U1	2.13
U2	3.24
U3	3.25
U4	2.51
Mean	2.75

4.5.1.6 Opportunity to learn in a coherent programme (OTL15)

Table 4.37 presents the means scores for the OTL in a coherent programme for each university. The mean scores for U1, U2, U3 and U4 are M = 2.8; M = 3.6; M = 3.7and M = 3.0, respectively. Respondents from U3 (3.7) indicate that they are afforded the most OTL in a coherent programme, followed by U2 (3.6) and U4 (3.0), while respondents from U1 (2.8) indicate that they are afforded the least OTL in a coherent programme. The average score for OTL in a coherent programme for the universities is 3.2.

Table 4.37: OTL in a coherent programme mean scores

University	OTL15
U1	2.77
U2	3.56
U3	3.72
U4	2.96
Mean	3.21

4.5.2 ANOVA and post-hoc tests for the OTL scores

The statistics below provide data on the ANOVA and the post-hoc tests for OTL mean scores.

4.5.2.1 ANOVA test for OTL tertiary-level physics and chemistry (OTL1)

Table 4.38 presents ANOVA test statistics for OTL tertiary-level physics and chemistry. It indicates that the universities' OTL tertiary-level physics and chemistry mean scores differ significantly (F = 7.214, p = 0.00).

Table 4.38: ANOVA test for the OTL tertiary-level physics and chemistry mean scores

		Sum of Squares	df	Mean Square	F	Sig.
OTL1	Between Groups	0.615	3	0.205	7.214	0.000
	Within Groups	3.070	108	0.028		
	Total	3.686	111			

Levene's test of homogeneity of variances in Table 4.39 indicates that equal variances are not assumed for OTL tertiary physics and chemistry (F(3,108) = 7.77, p = 0.00).

Table 4.39: Levene's test for homogeneity of variances of the OTL tertiary-level physics and chemistry mean scores

	Levene Statistic	df1	df2	Sig.
OTL1	7.77	3	108	0.000

Table 4.40 presents the Games-Howell post-hoc test. It indicates that U2 (0.93) and U3 (0.92) OTL mean scores are not statistically significantly equivalent to U1 (0.75) and U4 (0.80). The post-hoc test further shows that U2 and U3 variable scores are statistically significantly equivalent as well as U1 and U4.

Table 4.40: Test of Homogeneity of Variances (OTL tertiary-level physics and chemistry)

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
OTL1	U1	U2	-0.17*	0.00
		U3	-0.17*	0.00
		U4	-0.05	0.71
	U2	U1	0.17*	0.00
		U3	0.00	0.99
		U4	0.12*	0.02
	U3	U1	0.17*	0.00
		U2	-0.00	0.99
		U4	0.12*	0.04
	U4	U1	0.05	0.71
		U2	-0.12*	0.02
		U3	-0.12*	0.04

4.5.2.2 ANOVA test for OTL school-level physical science (OTL2)

Table 4.41 presents ANOVA test statistics for OTL school-level physical science. It indicates that the universities' OTL school-level physical science mean scores are statistically equivalent (F = 2.549, p = 0.060) and there is therefore no need to do post-hoc tests.

Table 4.41: ANOVA test for the OTL school-level physical science mean scores

		Sum of Squares	df	Mean Square	F	Sig.
OTL2	Between Groups	0.346	3	0.115	2.549	0.060
	Within Groups	4.891	108	0.045		
	Total	5.237	111			

4.5.2.3 ANOVA test for OTL physical science pedagogy (OTL6)

Table 4.42 presents ANOVA test statistics for OTL physical science pedagogy. It indicates that the universities' OTL physical-science pedagogy mean scores differ significantly (F = 10.201, p = 0.00).

Table 4.42: ANOVA test for the OTL physical science pedagogy mean scores

		Sum of Squares	df	Mean Square	F	Sig.
OTL6	Between Groups	11.082	3	3.694	10.201	0.000
	Within Groups	39.106	108	0.362		
	Total	50.187	111			

Levene's test of homogeneity of variances in Table 4.43 indicates that equal variances are not assumed for OTL physical science pedagogy (*F*(3,108) = 12.66, p = 0.00).

Table 4.43: Levene's test for homogeneity of variances of the OTL physical science pedagogy mean scores

	Levene Statistic	df1	df2	Sig.
OTL6	12.66	3	108	0.000

Table 4.44 presents the Games-Howell post-hoc test and it indicates that U2 (3.2) and U3 (3.3) OTL-variable mean scores are not statistically significantly equivalent to U1 (2.4) and U4 (2.8). The post-hoc test further shows that U2 and U3 variable scores are statistically significantly equivalent as well as U1 and U4.

Table 4.44: Test of Homogeneity of Variances (OTL physical science pedagogy)

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
OTL6	U1	U2	-0.77*	0.00
		U3	-0.84*	0.00
		U4	-0.35	0.28
	U2	U1	0.77*	0.00
		U3	-0.06	0.93
		U4	0.42*	0.00
	U3	U1	0.84*	0.00
		U2	0.06	0.93
		U4	0.48*	0.00
	U4	U1	0.35	0.28
		U2	-0.42*	0.00
		U3	-0.48*	0.00

4.5.2.4 ANOVA test for OTL through reflection (OTL9)

Table 4.45 presents ANOVA test statistics for OTL through reflection. It indicates that the universities' OTL through reflection mean scores differ significantly (F = 5.51, p = 0.00).

Table 4.45: ANOVA test for the OTL through reflection mean scores

		Sum of Squares	df	Mean Square	F	Sig.
OTL9	Between Groups	7.277	3	2.426	5.513	0.001
	Within Groups	47.523	108	0.440		
	Total	54.800	111			

Levene's test of homogeneity of variances in Table 4.46 indicates that equal variances are not assumed for OTL through reflection ($F(3,108) = 13.43$, p = 0.00).

Table 4.46: Levene's test for homogeneity of variances of the OTL through reflection mean scores

	Levene Statistic	df1	df2	Sig.
OTL9	13.43	3	108	0.000

Table 4.47 presents the Games-Howell post-hoc test and it indicates that U2 (3.1) and U3 (3.5) OTL-variable mean scores are not statistically significantly equivalent to U1 (2.6) and U4 (2.8) scores. The post-hoc test further shows that there are other subsets to the data as indicated in Table 4.47.

Table 4.47: Test of Homogeneity of Variances (OTL through reflection)

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
OTL9	U1	U2	-0.56*	0.02
		U3	-0.74*	0.00
		U4	-0.24	0.65
	U2	U1	0.56*	0.02
		U3	-0.17	0.56
		U4	0.31	0.12
	U3	U1	0.74*	0.00
		U2	0.17	0.56
		U4	0.49*	0.02
	U4	U1	0.24	0.65
		U2	-0.31	0.12
		U3	-0.49*	0.02

4.5.2.5 ANOVA test for OTL through teaching practice

ANOVA for teaching time (OTL11)

Table 4.48 presents ANOVA test statistics of means for the amount of time PSTs are in charge of a classroom are not statistically significantly equivalent (F = 3.370, p = 0.02).

Table 4.48: ANOVA for teaching time mean scores

		Sum of Squares	df	Mean Square	F	Sig.
OTL11	Between Groups	9.781	3	3.260	3.370	0.021
	Within Groups	104.495	108	0.968		
	Total	114.277	111			

Levene's test of homogeneity of variances in Table 4.49 indicates that equal variances are not assumed for the amount of time PSTs are in charge of a classroom ($F(3,108) = 3.53$, p = 0.02).

Table 4.49: Levene's test for homogeneity of variances of the teaching time mean scores

	Levene Statistic	df1	df2	Sig.
OTL11	3.53	3	108	0.017

The post-hoc test indicates all the four universities scores are statistically significantly equivalent.

Table 4.50: Test of Homogeneity of Variances (teaching time)

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
OTL11	U1	U2	-0.61	0.11
		U3	-0.75	0.06
		U4	-0.12	0.97
	U2	U1	0.61	0.11
		U3	-0.13	0.93
		U4	0.49	0.14
	U3	U1	0.75	0.06
		U2	0.13	0.93
		U4	0.62	0.07
	U4	U1	0.12	0.97
		U2	-0.49	0.14
		U3	-0.62	0.07

ANOVA for the presence of a mentor teacher while teaching (OTL12)

Table 4.51 presents ANOVA test statistics for the amount of time a mentor teacher is present while PSTs are in charge of a class indicates that the mean scores are not statistically significantly equivalent (F = 8.709, p = 0.00).

Table 4.51: ANOVA test for the presence of a mentor teacher while teaching mean scores

		Sum of Squares	df	Mean Square	F	Sig.
OTL12	Between Groups	23.571	3	7.857	8.709	0.000
	Within Groups	97.429	108	0.902		
	Total	121.000	111			

Levene's test of homogeneity of variances in Table 4.52 indicates that equal variances are not assumed for the amount of time a mentor teacher is present while PSTs are in charge of a class ($F(3,108) = 9.60$, p = 0.00).

Table 4.52: Levene's test for homogeneity of variances of the presence of a mentor teacher while teaching mean scores

	Levene Statistic	df1	df2	Sig.
OTL12	9.60	3	108	0.000

Table 4.53 presents the Games-Howell post-hoc test. It indicates that U2 (3.3) and U3 (3.5) OTL mean scores are not statistically significantly equivalent to U1 (2.8) and U4 (2.9) scores.

The post-hoc test further shows that U2 and U3 mean scores are statistically significantly equivalent and U1 and U4 mean scores are statistically significantly equivalent as well.

Table 4.53: Test of Homogeneity of Variances (the presence of a mentor teacher while teaching)

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
OTL12	U1	U2	-1.11*	0.00
		U3	-1.12*	0.00
		U4	-0.38	0.45
	U2	U1	1.11*	0.00
		U3	-0.01	1.00
		U4	0.73*	0.01
	U3	U1	1.12*	0.00
		U2	0.00	1.00
		U4	0.73*	0.04
	U4	U1	0.38	0.45
		U2	-0.73*	0.01
		U3	-0.73*	0.04

ANOVA test for OTL through teaching practice

Table 4.54 presents ANOVA test statistics for OTL through teaching practice and it indicates that the mean scores are not statistically significantly equivalent (F = 15.175, p = 0.00).

Table 4.54: ANOVA test for the OTL through teaching practice mean scores

		Sum of Squares	df	Mean Square	F	Sig.
OTL14	Between Groups	13.374	3	4.458	15.175	0.000
	Within Groups	31.728	108	0.294		
	Total	45.103	111			

Levene's test of homogeneity of variances in Table 4.55 indicates that equal variances are not assumed for the OTL through teaching practice ($F(3,108) = 9.31$, p = 0.00) for the OTL variables.

Table 4.55: Levene's test for homogeneity of variances of the OTL through teaching practice mean scores

	Levene Statistic	df1	df2	Sig.
OTL14	9.31	3	108	0.000

Table 4.56 presents the Games-Howell post-hoc test. It indicates that U2 (3.4) and U3 (3.5) OTL variable mean scores are not statistically significantly equivalent to U1 (2.6) and U4 (2.8)

scores. The post-hoc test further shows that U2 and U3 variable scores are statistically significantly equivalent and U1 and U4 mean scores are statistically significantly equivalent as well.

Table 4.56: Test of Homogeneity of Variances (OTL through teaching practice)

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
OTL14	U1	U2	-0.84*	0.00
		U3	-0.72*	0.00
		U4	-0.20	0.61
	U2	U1	0.84*	0.00
		U3	0.11	0.66
		U4	0.63*	0.00
	U3	U1	0.72*	0.00
		U2	-0.11	0.66
		U4	0.52*	0.00
	U4	U1	0.20	0.61
		U2	-0.63*	0.00
		U3	-0.52*	0.00

4.5.2.6 ANOVA test for OTL in a coherent programme (OTL15)

Table 4.57 presents ANOVA test statistics for OTL in a coherent programme and it indicates that the mean scores are not statistically significantly equivalent (F = 9.75, p = 0.00).

Table 4.57: ANOVA test for the OTL in a coherent programme mean scores

		Sum of Squares	df	Mean Square	F	Sig.
OTL15	Between Groups	11.438	3	3.813	9.751	0.000
	Within Groups	42.228	108	0.391		
	Total	53.666	111			

Levene's test of homogeneity of variances in Table 4.58 indicates that equal variances are not assumed for the OTL in a coherent programme ($F(3,108) = 11.87$, p = 0.00).

Table 4.58: Levene's test for homogeneity of variances of the OTL in a coherent programme mean scores

	Levene Statistic	df1	df2	Sig.
OTL15	11.87	3	108	0.000

Table 4.59 presents the Games-Howell post-hoc test. It indicates that U2 (3.6) and U3 (3.7) OTL mean scores are not statistically significantly equivalent to U1 (2.8) and U4 (3.0) scores. The post-hoc test further shows that U2 and U3 variable scores are statistically significantly equivalent, and U1 and U4 mean scores are statistically significantly equivalent as well.

Table 4.59: Test of Homogeneity of Variances (OTL in a coherent programme)

Dependent Variable	(I) U_Num	(J) U_Num	Mean Difference	Sig.
OTL15	U1	U2	-0.67*	0.00
		U3	-0.88*	0.00
		U4	-0.21	0.72
	U2	U1	0.67*	0.00
		U3	-0.20	0.28
		U4	0.46*	0.00
	U3	U1	0.88*	0.00
		U2	0.20	0.28
		U4	0.66*	0.00
	U4	U1	0.21	0.72
		U2	-0.46*	0.00
		U3	-0.66*	0.00

4.5.2.7 Summary of the OTL scores

The ANOVA tests for the OTL variables indicate that there are statistically significant differences between the OTL mean scores of the universities with the exception of OTL2. Furthermore, the tables reveal that on average, respondents from U3 report that they are afforded the highest number of OTL followed by respondents from U2 and U4 while respondents from U1 report the lowest OTL mean score. ANOVA and post hoc tests reveal that U2 and U3 mean scores are statistically equivalent and the tests also show that U4 and U1 scores are statistically equivalent.

4.6 Research question one

What is the level of knowledge of pre-service physical science teachers in some South African universities?

Mean scores for CK and PCK scores of all the respondents are presented in the tables below.

4.6.1 CK and PCK scores

Table 4.60: CK score of the sample

Item	Mean	Standard deviation
CK1P	0.51	0.50
CK2P	0.50	0.50
CK3P	0.63	0.48
CK4P	0.54	0.50
CK5P	0.63	0.48
CK6C	0.67	0.47
CK10C	0.54	0.50
CK11P	0.53	0.50
CK12P	0.46	0.50
CK13C	0.43	0.49
CK14C	0.54	0.50
CK15C	0.50	0.50
CK18C	0.46	0.50
CK19C	0.55	0.49
CK21C	0.54	0.50
CK22C	0.46	0.50
CK23P	0.51	0.50
CK24P	0.39	0.49

Table 4.60 presents the CK scores of the entire sample of PSTs. The mean scores show that item CK24P received the least number of correct responses with a mean score of 0.39 and item CK6C received the most number of correct responses with a mean score of 0.67.

Table 4.61: PCK scores of the sample

Item	Mean	Standard deviation
PCK7	0.67	0.47
PCK8	0.57	0.49
PCK9	0.62	0.48
PCK16	0.57	0.49
PCK17	0.55	0.49
PCK20	0.56	0.49

Table 4.61 presents the PCK scores of the respondents. The scores show that item PCK17 received the least correct responses, with a mean score of 0.55 and item PCK7 received the most number of correct responses, with a mean score of 0.67.

4.6.2 Summary of the knowledge scores

The findings from the knowledge scores reveal that 13 out of the 18 CK items' mean scores are over 0.5 and all the PCK items' mean scores are above 0.5, indicating the PSTs did not find the two tests too difficult. The mean score of the CK items is M = 0.52, SD = 0.21 and although the achievement score indicates adequate achievement according to South African standards (50% represents a pass mark in universities), the mean score may not be adequate in the context of final-year PSTs. The expectation is that the same PSTs will be teaching some of the content that the items are based on and the fact that the mean achievement score can be considered as a borderline score is a cause for concern. This finding is similar to what Aksan and Çelikler (2015) find in their study. They found that PSTs' CK had gaps in their knowledge and they further asserted that these gaps will likely affect teaching and learning negatively. Much like what the finding in the present study suggests, Rice (2005) also found that although some PSTs could identify the correct option, they could not readily support their answer with an accurate description or explanation. The mean CK score suggests that the PSTs' CK is not sufficient for the eventual teaching of physical science. Although, to some extent, their PCK scores are fair, the lack of proper understanding of physical science concepts will likely hinder the effectiveness of their lessons (McConnell *et al.*, 2013).

4.7 Research question two

What are PSTs' beliefs about teaching and learning of physical science?

Mean scores of PSTs' belief bundles are presented below.

4.7.1 Beliefs about the nature of science

Table 4.62 presents beliefs about the nature of science scores. The scores show that item BLF1F has the lowest mean (M = 3.21, SD = 1.80) and item BLF1C has the highest mean scores (M = 4.90, SD = 1.17). Two of the items (BLF1A and BLF1B) are negatively worded and their scores are recoded such that the desirable beliefs have higher numbers, i.e. 4, 5 and 6.

Table 4.62: Beliefs about the nature of science

Code	Item	Mean	Standard deviation
BLF1A*	A. Physical science is a collection of rules and theories that control the universe	3.81	1.71
BLF1B*	B. Physical science involves the remembering and application of definitions, formulas, facts and calculations.	3.45	1.74
BLF1C	C. Physical science involves creativity and new ideas.	4.90	1.17
BLF1D	D. In physical science, many things can be discovered and tried out by one's self.	4.72	1.28
BLF1E	E. Fundamental to physical science is generation of knowledge and facts	4.60	1.30
BLF1F	F. To do physical science requires much practice, correct application of laws, and problem solving strategies.	3.21	1.80

Beliefs about the nature of science scores illustrate that PSTs believe that science has to do with the generation of new knowledge using creative thinking and new ideas. They also believe that the knowledge generated in science can be tried and tested by oneself. To a lesser extent, the PSTs' scores indicate that they do not believe that science is a collection of rules and facts that control the universe. PSTs further believe that practice, correct application of laws and the ability to solve problems are important aspects with regard to the nature of science.

4.7.2 Beliefs about learning science

Table 4.63 presents beliefs about learning science mean scores. The mean scores show that item BLF2B has the lowest mean (M = 3.93, SD = 1.56) and item BLF2D has the highest mean score (M = 4.70, SD = 1.34). All but one of the items (BLF2D) are negatively worded and their scores are recoded such that the desirable beliefs have higher numbers.

Table 4.63: Beliefs about learning physical science scores

Code	Item	Mean	Standard deviation
BLF2A*	A. The best way to do well in physical science is to memorize all the theories and laws.	4.60	1.36
BLF2B*	B. Learners need to be taught exact procedures for solving physical science problems.	3.93	1.56
BLF2C*	C. It does not really matter if you understand a physical science problem, if you can get the right answer.	4.69	1.38
BLF2D	D. In addition to getting a right answer in physical science, it is important to understand why the answer is correct.	4.70	1.34
BLF2E*	E. Non-standard procedures and processes should be discouraged because they can interfere with learning the correct procedures and processes.	4.26	1.50
BLF2F*	F. Hands-on physical science experiences are not worth the time and expense.	4.45	1.45

Beliefs about learning science scores suggest that PSTs are of the view that physical science is not just a collection of facts, laws and procedures that need to be taught to learners, but in addition to getting the right answer, learners must understand why the particular answer is correct. The scores also indicate that PSTs support the use of non-standard procedures to solve problems and they see value in the use of hands-on activities to enhance the conceptual understanding of learners. The finding seems to suggest that the PSTs in this study believe that learner-centred approaches are desirable. This finding is unlike Simmons *et al*'s (1999) finding where the assertion is that PSTs' beliefs wobbled between teacher-centred to learner-centred approaches. The findings also indicate that, unlike Yilman-Tuzman and Topcu's (2008) study of students in Turkey, who believed that students should be encouraged to memorise facts and laws, the respondents in the present study are of the view that science is learned better through experimentation. Davis *et al* (2006) suggest that PSTs encourage memorisation of facts, because they believe it will improve learner success.

4.7.3 Beliefs about science achievement scores

Table 4.64 presents beliefs about science achievement scores. The scores show that item BLF3E has the lowest mean (M = 3.67; SD = 1.93) and item BLF3C has the highest mean scores (M = 4.91, SD = 1.39). All the items are negatively worded and their scores are recoded such that the desirable beliefs have higher numbers.

Table 4.64: Beliefs about physical science achievement

Code	Item	Mean	Standard deviation
BLF3A*	A. Since older learners can reason abstractly, the use of hands-on models and other visual aids becomes less necessary.	4.76	1.25
BLF3B*	B. Physical science is a subject in which natural ability matters a lot more than effort.	4.47	1.42
BLF3C*	C. In general, boys tend to be naturally better at physical science than girls are.	4.91	1.39
BLF3D*	D. Physical science ability is something that remains relatively fixed throughout a person's life.	4.45	1.64
BLF3E*	E. Some people are good at physical science and some are not.	3.67	1.93
BLF3F*	F. Some ethnic groups are better at physical science than others are.	4.57	1.69

Beliefs about science achievement scores suggest that PSTs reject the idea that certain groups tend to be better in physical science than others are. For example, the scores suggest that physical science achievement is independent of factors such as ethnicity and gender. Furthermore, the scores illustrate that PSTs believe that learners' abilities change and even if a learner has a certain level of ability with regard to physical science, effort from the leaner is still important. This is unlike Georgiou and Tourva's (2007) findings where PSTs believed that achievement had little to do with learner effort. The finding is also in agreement with Yilman-Tuzman and Topcu's (2008) finding where PSTs believed that innate ability of students was not fixed and might be affected by effective teaching.

4.7.4 Beliefs about preparedness for teaching physical science scores

Table 4.65 presents beliefs about preparedness for teaching scores. The scores show that item BLF4A and BLF4I have the lowest mean (M = 3.11, SD = 0.97 & SD = 1.09) and item BLF4E has the highest mean score (M = 3.26, SD = 1.00). No items in the variable required re-coding.

Table 4.65: Beliefs about preparedness for teaching physical science

Code	Item	Mean	Standard deviation
BLF4A	A. Establish appropriate learning goals in physical science for learners	3.11	0.97
BLF4B	B. Set up physical science learning activities to help learners achieve learning goals	3.25	0.98
BLF4C	C. Use questions to promote higher order thinking in physical science	3.25	0.99
BLF4D	D. Use computers and ICT to aid in teaching physical science	3.12	1.01
BLF4E	E. Challenge learners to engage in critical thinking about physical science	3.26	1.00
BLF4F	F. Establish a supportive environment for learning physical science	3.19	1.02
BLF4G	G. Use assessment to give effective feedback to learners about their physical science learning	3.25	1.02
BLF4H	H. Develop assessment tasks that promote learning in physical science	3.20	1.06
BLF4I	I. Use assessment to give effective feedback to learners about their physical science learning	3.11	1.09
BLF4J	J. Have a positive influence on difficult or unmotivated learners	3.17	1.06

Scores pertaining to beliefs about preparedness for teaching physical science indicate that the PSTs believe that they are sufficiently prepared to teach physical science in schools. The scores indicate that they believe they can plan for lessons and use appropriate assessment strategies. They also believe that they can foster conducive learning environments that are supported by relevant ICTs, if necessary, and they can prepare activities and questions that promote higher-order and critical thinking in physical science.

4.7.5 Beliefs about programme effectiveness scores

Table 4.66 presents beliefs about programme effectiveness scores. The scores show that item BLF5C has the lowest mean (M = 4.48, SD = 1.40) and item BLF5E has the highest mean (M = 4.83, SD = 1.34). No items in the variable required re-coding.

Table 4.66: Beliefs about programme effectiveness

Code	Item	Mean	Standard deviation
BLF5A	A. Model good teaching practices in their teaching	4.64	1.33
BLF5B	B. Draw on and use research relevant to the content of their courses	4.58	1.34
BLF5C	C. Model evaluation and reflection on their own teaching	4.48	1.40
BLF5D	D. Value the learning and experiences you has prior to starting the programme	4.68	1.39
BLF5E	E. Value the learning and experiences you has in your field experience and or practicum	4.67	1.30
BLF5F	F. Value the learning and experiences you has in your teacher preparation programme	4.83	1.34

Beliefs about programme effectiveness scores reveal that PSTs believe that their teacher education programmes are effective. The scores indicate that PSTs believe that their instructors value their experiences from before they commenced with their training and their experiences during training. Similar to the present study's findings, Tillotson and Young (2013) found that PSTs in their study believed they were trained in a quality programme and they would recommend the programme to other prospective teachers.

4.7.6 Summary of the belief bundles scores

The mean scores of the beliefs variables indicate that on average, PSTs hold desirable beliefs (M > 3). The acknowledgement of these beliefs is important, because teachers enter their teacher education with certain beliefs, be it desirable or undesirable beliefs (Ackay & Yager, 2010). Proper acknowledgement of such beliefs may provide a space for instructors to try to influence the beliefs in a positive manner (Tatar, 2015).

4.8 Research question three

What kinds of OTL are pre-service science teachers exposed to in some South African universities?

Mean scores for OTL are presented below.

4.8.1 OTL tertiary level physics and chemistry topics

Table 4.67 and Table 4.68 present the OTL scores for tertiary physics and chemistry topics. The scores show that the physics topic with the highest score is item OTLP1A (M = 0.91) and the item with the lowest score is OTLP1T (M = 0.36). The data also show that the chemistry topics that have the highest scores are items OTLC1A, OTLC1C, OTLC1F and OTLC1T (M = 0.91) and the item with the lowest score is OTLC1S (M = 0.47).

Table 4.67: OTL tertiary physics topics scores

Code	Item	Mean	Standard deviation
OTLP1A	A. **Motion along a straight line** (position, displacement, velocity, acceleration)	0.91	0.28
OTLP1B	B. **Motion in two or three dimension** (Vectors, average velocity, acceleration, projectile motion, uniform circular motion)	0.88	0.33
OTLP1C	C. **Force and motion** (mass, force, Newtonian laws, friction, terminal speed)	0.90	0.29
OTLP1D	D. **Kinetic energy and Work** (Kinetic energy, kinetic energy and work, gravitational force and work, spring force and work, work done by variable force)	0.88	0.33
OTLP1E	E. **Potential energy and conservation of energy** (Work and potential energy, mechanical energy, conservation of energy, work done by/on a system,	0.89	0.31
OTLP1F	F. **Centre of mass and linear motion** (linear momentum, collision and impulse, conservation of linear momentum, collision in two dimensions)	0.86	0.35
OTLP1G	G. **Rolling, rotation, torque and angular momentum** (rotational variables, kinetic energy and rotation, torque, angular momentum, gyroscopes)	0.87	0.34
OTLP1H	H. **Gravitation** (Laws of gravitation, gravitation and superposition, gravitation near and inside the earth, Kepler’s laws, Einstein and gravitation	0.85	0.36
OTLP1I	I. **Fluids** (density and pressure, fluids at rest, Pascal’s principle, Archimedes principle, fluids in motion, Bernoulli’s equation)	0.86	0.35

OTLP1J	J. **Oscillations and Waves** (Simple harmonic motion, pendulums, forced oscillations and resonance, types of waves, wavelength, Doppler effect)	0.88	0.33
OTLP1K	K. **Temperature, heat and laws of thermodynamics** (Celsius and Fahrenheit scales, laws of thermodynamics, thermal expansion, heat and work, entropy	0.88	0.32
OTLP1L	L. **Kinetic theory of gases** (Avogadro's number, ideal gases, pressure, rms speed, temperature, molar specific heat, quantum theory, adiabatic expansions)	0.87	0.34
OTLP1M	M. **Electric fields and charges** (field lines, electric fields due to point charges and electric dipoles, electric charges, coulombs law, conservation of charges)	0.88	0.33
OTLP1N	N. **Gaussian laws** (flux of electric field, Gauss laws and its applications)	0.88	0.33
OTLP1O	O. **Current, resistance and capacitance** (equipotential surfaces, electric current, resistance and resistivity, Ohm's law, semi and super conductors)	0.88	0.32
OTLP1P	P. **Circuits, Magnetic fields and inductance** (Work, energy, emf, circuits ammeters and voltmeters, Hall effect, solenoids, RC circuits, induced electric field, Alternating current.)	0.83	0.37
OTLP1Q	Q. **Maxwell equations, electromagnetic waves** (magnetism and electrons, images, interference, diffraction)	0.82	0.38
OTLP1R	R. **Relativity, photons and matter waves** (effects of relativity, photoelectric effect, Schrodinger's equations, Bohr's model of an atom, Heisenberg principle)	0.87	0.34
OTLP1S	S. **Atoms and nuclear physics** (properties of atoms, semiconductors, properties of the nucleus, energy form the nucleus	0.86	0.35
OTLP1T	T. **Quarks, leptons and the big bang** (The quark model, messenger particles, big bang)	0.36	0.48

Table 4.68: OTL tertiary chemistry topics scores

Code	Item	Mean	Standard deviation
OTLC1A	A. **Atoms, molecules and ions** (atomic theory and structure: chemical substances: formulas and names, chemical reactions: equations)	0.92	0.27
OTLC1B	B. **Chemical reactions** (Aqueous solutions, types of chemical reactions, balancing of chemical reactions)	0.88	0.33
OTLC1C	C. **Calculations with chemical formulas and equations** (mass and moles of substances, determining chemical formulae, stoichiometry, quantitative analysis)	0.92	0.27
OTLC1D	D. **Gaseous state** (Empirical gas law, ideal gas law, gas mixtures Kinetic molecular theory)	0.90	0.29
OTLC1E	E. **Thermodynamics** (Understanding heats of reactions, enthalpy, thermo-chemical reactions, Hess law, standard enthalpies of reaction.)	0.87	0.34
OTLC1F	F. **Quantum theory of the atom** (light waves, protons, Bohr theory, quantum mechanics and quantum numbers, atomic orbital)	0.92	0.27

OTLC1G	G. **Electron configuration and periodicity** (electric structure of the atom, orbital diagrams of atoms, periodicity of the elements, Mendelev predictions)	0.88	0.33
OTLC1H	H. **Ionic and covalent bonding** (ionic bonding, covalent bonds, Lewis structures and dot formulae)	0.88	0.32
OTLC1I	I. **Molecular geometry and chemical bonding theory** (molecular geometry, VSEPR model, molecular orbital theory, electron configurations	0.86	0.35
OTLC1J	J. **States of matter** (changes of state, liquid state, properties of liquids, intermolecular forces, solid state, crystal structures)	0.87	0.34
OTLC1K	K. **Solutions** (Solution formation, colligative properties, boiling point elevation, freezing point depression, colloid formation)	0.88	0.32
OTLC1L	L. **Rates of reactions** (reaction rates, dependence of the rate of reactions, reaction mechanisms, the rate law, catalysis)	0.84	0.36
OTLC1M	M. **Chemical equilibrium** (Describing chemical equilibrium, the equilibrium constant, Le Chatelier's principle)	0.88	0.33
OTLC1N	N. **Acids and bases** (acid-base concepts, acid base strengths, self-ionization of water, pH)	0.90	0.29
OTLC1O	O. **Acid-base equilibria** (solutions of weak acids and base, solutions of weak acid or base with another solute)	0.89	0.31
OTLC1P	P. **Solubility and complex-ion equilibria** (solubility equilibria, complex ion equilibria, applications of solubility equilibria	0.82	0.38
OTLC1Q	Q. **Electrochemistry** (Half reactions, voltaic cells, electrochemistry, emf and pH sensors	0.85	0.36
OTLC1R	R. **Nuclear chemistry** (radioactivity and nuclear bombardment reactions, energy of nuclear reactions)	0.76	0.43
OTLC1S	S. **Metallurgy and main group elements**	0.47	0.50
OTLC1T	T. **Organic chemistry** (Hydrocarbons, derivatives of hydrocarbons, mechanism, spectroscopy)	0.92	0.27

PSTs are normally exposed to university physics and chemistry as a way of enhancing their physical science CK. The physics topic that has the highest frequency is motion along a straight line and for chemistry, atoms, molecules and ions, including organic chemistry, have the highest frequencies. The topics with the lowest frequencies are quarks, leptons and the big bang for physics, and metallurgy, including main group elements for chemistry. The findings are consistent with the design of most teacher education programmes in South Africa. The MRTEQ (2015) policy document requires PSTs to have second-year physics and/or chemistry to teach FET-phase physical science and most of the topics where high frequencies are reported are treated in the first or second year of the PSTs' training. The topics that have the lowest frequencies, i.e. metallurgy, main group elements, quarks, leptons, and the big bang are considered to be advanced topics in both chemistry and physics and they are normally treated in the third year of study or beyond. The OTL mean scores for tertiary physics and chemistry therefore suggest that the PSTs are exposed to topics that are similar to those that form the bulk of the school physical science curriculum.

4.8.2 OTL school level physical science topics

Table 4.69 presents the OTL school-level physical science topics mean scores. The mean scores show that the physical science topic that has the highest score is item OTL2D (M = 0.96) and the items with the lowest scores are OTL2H and OTL2P (M = 0.87).

Table 4.69: OTL school-level physical topics scores

Code	Item	Mean	Standard deviation
OTL2A	A. **Vectors & scalars: Motion in one dimension** (reference frame, displacement and distance, average velocity, acceleration, instantaneous velocity)	0.94	0.24
OTL2B	B. **Newton's Laws and Application of Newton's Laws** (Newton's first, second and third laws and Newton's law of universal gravitation, different kinds of forces)	0.95	0.22
OTL2C	C. **Momentum and Impulse** (momentum, Newton's second law, conservation of momentum, elastic and inelastic collisions, Impulse)	0.94	0.24
OTL2D	D. **Vertical projectile motion in one dimension (1D)** (vertical projectile motion represented in words, diagrams, equations and graphs)	0.96	0.20
OTL2E	E. **Work, Energy & Power** (work, work-energy theorem, conservation of energy with non-conservative forces present, power)	0.93	0.25
OTL2F	F. **Transverse and Longitudinal waves (**wavelength, frequency, amplitude, period, wave speed, sound waves, pitch, loudness, quality (tone), ultrasound)	0.91	0.28
OTL2G	G. **Electromagnetic radiation** (dual (particle/wave) nature of electromagnetic (EM) radiation, nature of EM radiation, EM spectrum	0.88	0.32
OTL2H	H. **Geometrical Optics, 2D & 3D Wave fronts** (Refraction, Snell's Law, Critical angles and total internal reflection, Diffraction, **Doppler Effect**)	0.87	0.34

OTL2I	I. **Magnetism and Electrostatics (**magnetic field, attraction and repulsion, field lines, earth's magnetic field, two kinds of charge, force exerted by charges	0.93	0.25
OTL2J	J. **Electric circuits and electrodynamics** (emf, potential difference, current, resistance, resistors in parallel and series, electrical machines, alternating current)	0.91	0.28
OTL2K	K. **States of matter and the kinetic molecular theory** (materials, models of the atom; atomic mass; protons, neutrons and electrons; isotopes)	0.94	0.24
OTL2L	L. **Physical and chemical change** (separation by physical & chemical means; conservation principle; law of constant composition names and formulas).	0.92	0.27
OTL2M	M. **Molecular structure and Intermolecular forces (**a chemical bond; molecular shape; electronegativity and bond polarity, states of matter; density; kinetic energy)	0.91	0.28
OTL2N	N. **Ideal gases** (motion and kinetic theory of gases; gas laws; relationship between T and P)	0.92	0.27
OTL2O	O. **Atomic structure and Chemical bonding** (models of the atom; atomic mass and diameter; protons, neutrons and electrons, covalent, ionic & metallic bonding)	0.94	0.24
OTL2P	P. **Optical phenomena and properties of materials** (photo-electric effect, emission and absorption spectra)	0.87	0.34
OTL2Q	Q. **Organic chemistry** (functional groups; saturated and unsaturated structures; isomers; naming and formulae; physical properties; chemical reactions	0.93	0.25
OTL2R	R. **Stoichiometry** (molar volume of gases; concentration; limiting reagents; volume relationships in gaseous reactions)	0.89	0.31
OTL2S	S. **Reaction rate & Chemical equilibrium** (factors affecting rate; mechanism of reaction and of catalysis, factors affecting equilibrium; equilibrium constant)	0.90	0.29
OTL2T	T. **Electrochemical reactions** (electrolytic and galvanic cells; relation of current and potential to rate and equilibrium; standard electrode potentials; oxidation)	0.88	0.32
OTL2U	U. **Acids and bases** (reactions; titrations, pH, salt hydrolysis)	0.89	0.31

PSTs report that they have sufficient OTL school-level physical science according to their frequency scores (M > 0.85). The findings therefore suggest that teacher education programmes do expose PSTs to sufficient physical science content. Although PSTs report that they are afforded sufficient OTL school-level physical science, the manner in which they are exposed to it still needs more attention in the literature. It is unclear if this happens in their methods courses or if their content courses are customised to afford them this opportunity.

4.8.3 OTL physical science pedagogy

Table 4.70 presents the OTL physical science pedagogy mean scores. The scores show that the OTL physical science pedagogy item with the highest mean score is OTL6D (M = 3.29; SD = 0.85) and the item with the lowest score is OTL6E (M = 2.69; SD = 0.97).

Table 4.70: OTL physical science pedagogy scores

Code	Item	Mean	Standard deviation
OTL6A	A. Accommodate a wide range of abilities in each lesson	2.75	0.98
OTL6B	B. Analyse pupil assessment data to learn how to assess more effectively	2.84	0.94
OTL6C	C. Assess higher−level goals (e.g. problem-solving, critical thinking)	3.00	0.90
OTL6D	D. Assess low−level objectives (factual knowledge, routine procedures and so forth)	3.29	0.85
OTL6E	E. Create learning experiences that make the central concepts of subject matter meaningful to learners	2.69	0.97
OTL6F	F. Deal with learning difficulties so that specific pupil outcomes are accomplished	2.95	1.03
OTL6G	G. Develop instructional materials that build on learners' experiences, interests and abilities	2.79	0.99
OTL6H	H. Help learners learn how to assess their own learning	2.95	0.98
OTL6I	I. Use learners' misconceptions to plan instruction	2.83	1.02
OTL6J	J. Integrate physical science ideas from across areas of science	3.00	0.96

OTL science pedagogy mean scores also suggest that PSTs are afforded sufficient opportunities to engage with pedagogy specific to physical science. PSTs' mean scores suggest that they are afforded the opportunity engage in assessment and analysis of learner data, as well as to create a conducive learning environment. The findings therefore propose that PSTs are afforded sufficient OTL physical science pedagogy.

4.8.4 OTL through reflection scores

Table 4.71 presents OTL through reflection scores. The scores show that the OTL through reflection item with the highest mean score is OTL9D (M = 3.07; SD = 0.97) and the item with the lowest score is OTL9A (M = 2.69; SD = 0.96).

Table 4.71: OTL through reflection scores

Code	Item	Mean	Standard deviation
OTL9A	A. Develop research projects to test teaching strategies for learners of diverse abilities	2.69	0.96
OTL9B	B. Consider the relationship between education, social justice and democracy	2.76	0.96
OTL9C	C. Identify appropriate resources needed for teaching	3.01	0.85
OTL9D	D. Observe teachers modelling new teaching practices	3.07	0.97
OTL9E	E. Develop and test new teaching practices	3.00	0.98
OTL9F	F. Set appropriately challenging learning expectations for learners	2.83	1.04
OTL9G	G. Learn how to use findings from research to improve knowledge and practice	2.83	1.04
OTL9H	H. Connect learning across subject areas	2.96	0.94
OTL9I	I. Create methods to enhance learners' confidence and self-esteem	2.87	1.04

PSTs' scores on the OTL to teach physical science through reflective practices indicate that their programmes provide them with opportunities to engage in reflection. The PSTs' scores illustrate that they have the opportunity to reflect on their ability to identify appropriate resources needed for teaching, develop and test new strategies, and use research findings to inform their practice. The findings therefore propose that PSTs are afforded sufficient OTL teaching using reflective practices.

4.8.5 OTL through teaching practice

Table 4.72 presents PSTs' mean scores with regard to time spent in the classroom. The scores show that the mean score of time spent while in charge of a class is M = 3.08, SD = 1.01 and the mean score of time spent in class and in the presence of a mentor is M = 2.75, SD = 1.04.

Table 4.72: OTL through teaching time scores

Code	Item	Mean	Standard deviation
OTL11	For what proportion of this time are you temporarily in charge of teaching the class (as opposed to observation, assistance, and individual tutoring)?	3.08	1.01
OTL12	For about how much of the time in the field experience, is one of your assigned mentors present in the same room as you?	2.75	1.04

Table 4.73 presents OTL through teaching practice scores. The scores show that the item of OTL through teaching practice that has the highest mean score is OTL14B (M = 3.19, SD = 0.96) and the item with the lowest score is OTL14H (M = 2.24, SD = 1.13).

Table 4.73: OTL through teaching practice

Code	**Item**	**Mean**	**Standard deviation**
OTL14A	A. I has a clear understanding of what my school-based mentor expected of me as a teacher in order to pass the field experiences.	2.97	1.04
OTL14B	B. My school-based mentor valued the ideas and approaches I brought from my university teacher education program.	3.19	0.96
OTL14C	C. My school-based mentor used criteria provided by my university when reviewing my lessons with me.	3.05	0.93
OTL14D	D. In my field of experience, I have to demonstrate to my supervising teacher that I could teach according to the same criteria used in my university course.	2.97	1.01
OTL14E	E. The feedback I received from my mentor helped me to improve my teaching methods.	3.13	0.86
OTL14F	F. The feedback I received from my mentor helped me to improve my knowledge of physical science content.	2.96	0.99
OTL14G*	G. The methods of teaching I used in my field experiences are quite different from the methods I learned in my university course.	2.40	1.06
OTL14H*	H. The regular supervising teacher in my field experiences classroom taught in ways that are quite different from the methods I learned in my university course.	2.24	1.13

OTL scores to learn through teaching practice illustrate that PST are also afforded time to teach classes during their teaching practice (M = 3.08, SD = 1.04). Their scores also reveal that, to a lesser extent, a mentor teacher is present when they are in charge of a class (M =

2.75, SD = 1.04). The PSTs' scores show that they have the OTL from their mentor teachers. PSTs also report that they have the opportunity to illustrate their teaching strategies and discuss new ideas with their mentor teachers. The scores further show that PSTs know what is expected of them in schools and they value the feedback they received from their mentor teachers. Interestingly, the scores marginally suggest that the methods PSTs and their mentor teachers use in the classroom are quite different from the methods the PSTs learn in their respective programmes. The findings therefore propose that PSTs are afforded sufficient OTL from teaching practice.

4.8.6 OTL in a coherent teacher education programme

Table 4.74 presents the OTL in a coherent programme scores. The scores show that the OTL item in a coherent programme that has the highest mean score is OTL15D (M = 3.23, SD = 0.86) and the item with the lowest score is OTL15F (M = 3.08, SD = 0.96).

Table 4.74: OTL in a coherent teacher education programme scores

Code	Item	Mean	Standard deviation
OTL15A	A. Each stage of the programme seemed to be planned to meet the main needs I had at that stage of my preparation.	3.09	0.83
OTL15B	B. Later courses in the programme built on what was taught in earlier courses in the programme.	3.09	0.96
OTL15C	C. The programme is organised in a way that covered what I needed to learn to become an effective teacher.	3.11	0.87
OTL15D	D. The courses seemed to follow a logical sequence of development in terms of content and topics.	3.23	0.86
OTL15E	E. Each of my courses is clearly designed to prepare me to meet a common set of explicit standard expectations for beginner teachers.	3.10	0.89
OTL15F	F. There are clear links between most of the courses in my teacher education programme.	3.08	0.96

PSTs' scores indicate that they have the OTL in a coherent teacher education programme. PSTs' scores reveal that their programmes are well organised and the courses follow a logical sequence. The scores also show that PSTs have the OTL in a programme that is designed to prepare them to meet the expectations of a beginner teacher. The findings therefore propose that PSTs are afforded sufficient OTL in a coherent programme.

4.8.7 Summary of the OTL scores

In summary, the PSTs' mean scores seem to suggest that they are afforded sufficient OTL in their respective teacher education programmes. All the assessed OTL mean scores are above the mid-point, which indicates that PSTs are, on average, of the opinion that they are afforded sufficient OTL.

4.9 Research question four

What are the relationships between PSTs' knowledge, beliefs and the OTL they are exposed to?

Correlations are employed in the present study to assess relationships between the OTL variables and PSTs' knowledge and belief bundles. The dependent variables CK and PCK form the knowledge construct and the belief bundles construct consists of beliefs about the nature of science, learning science, science achievement, preparedness for teaching physical science and programme effectiveness. The independent variables are OTL tertiary physics and chemistry, OTL school physical science, OTL physical science pedagogy, OTL through reflection, OTL through teaching practice and OTL in a coherent teacher education programme. Correlation for the knowledge construct are presented first, followed by correlation coefficients for the belief bundles construct.

4.9.1 Correlations for the knowledge construct

Correlations between the knowledge construct and OTL variables are presented below.

4.9.1.1 Correlations between OTL tertiary-level physics and chemistry, and PSTs' knowledge (CK and PCK)

Table 4.75 presents the range of the correlation coefficients between OTL tertiary-level physics and knowledge (CK and PCK) mean scores. The range of the coefficients is as follows: CK (0.03 < r < 0.35) and PCK (-0.16 < r < 0.34).

Table 4.76 presents the range of the correlation coefficients between OTL tertiary-level chemistry and knowledge (CK and PCK) mean scores. The range of the coefficients is as follows: CK (-0.04 < r < 0.38) and PCK (-0.09 < r < 0.30).

Table 4.75: Correlations between OTL tertiary-level physics and PSTs' CK and PCK

	Content knowledge		Pedagogical content knowledge	
Code	r	p-value	r	p-value
OTLP1A	0.21*	0.03	-0.03	0.73
OTLP1B	0.13	0.19	-0.04	0.65
OTLP1C	0.15	0.12	-0.08	0.39
OTLP1D	0.21*	0.03	0.11	0.26
OTLP1E	0.25**	0.01	0.09	0.33
OTLP1F	0.27**	0.00	0.00	0.97
OTLP1G	0.20*	0.04	-0.07	0.47
OTLP1H	0.18	0.06	0.01	0.94
OTLP1I	0.26**	0.01	0.34**	0.00
OTLP1J	0.21*	0.03	0.01	0.89
OTLP1K	0.11	0.24	0.06	0.52
OTLP1L	0.03	0.79	-0.16	0.09
OTLP1M	0.15	0.12	-0.10	0.3
OTLP1N	0.35**	0.00	0.24*	0.01
OTLP1O	0.13	0.18	-0.02	0.87

Table 4.76: Correlations between OTL tertiary-level chemistry and PSTs' CK and PCK

	Content knowledge		Pedagogical content knowledge	
Code	r	p-value	r	p-value
OTLC1A	0.23*	0.02	0.11	0.23
OTLC1B	0.11	0.24	0.11	0.26
OTLC1C	0.07	0.44	-0.02	0.8
OTLC1D	0.16	0.09	0.17	0.07
OTLC1E	0.08	0.39	0.08	0.41
OTLC1F	0.10	0.29	0.00	0.99
OTLC1G	0.13	0.19	-0.01	0.96
OTLC1H	0.12	0.21	0.14	0.14
OTLC1I	0.19*	0.04	0.07	0.47
OTLC1J	0.06	0.52	0.02	0.81
OTLC1K	0.14	0.13	0.12	0.21
OTLC1L	0.07	0.46	0.19*	0.05
OTLC1M	0.18	0.06	0.20*	0.03
OTLC1N	0.11	0.26	0.00	0.99
OTLC1O	0.22*	0.02	0.30**	0.00

OTLP1P	0.04	0.68	-0.09	0.34
OTLP1Q	0.30**	0.00	0.11	0.23
OTLP1R	0.22*	0.02	0.06	0.53
OTLP1S	0.24*	0.01	0.14	0.14
OTLP1T	0.20*	0.03	0.16	0.10

OTLC1P	0.17	0.07	0.08	0.39
OTLC1Q	0.15	0.11	0.20*	0.04
OTLC1R	0.38**	0.00	0.33**	0.00
OTLC1S	-0.04	0.69	-0.09	0.33
OTLC1T	0.37**	0.00	0.21*	0.03

**r significant at p < 0.05 and **r significant at p < 0.01*

The correlations of the OTL tertiary-level physics and chemistry, and CK scores reveal that all the correlation coefficients for OTL physics are positive and only one correlation coefficient for chemistry is negative. Physics topics have more positive significant, but weak correlation coefficients than chemistry topics, which suggests that PSTs' CK is associated with having the OTL physics topics than chemistry topics. The correlation coefficients of the OTL tertiary-level physics and chemistry, and PCK scores reveal that there are positive and negative weak associations for both OTL. There are also slightly more significant correlation coefficients between the OTL chemistry than OTL physics and PCK. The findings indicate that there are no clear trends between OTL tertiary-level physics and chemistry, and PCK scores, although the OTL tertiary-level chemistry coefficients suggests there might be weak positive associations between OTL tertiary-level science and PCK. Similar findings have been reported by Monk (1994) that OTL tertiary-level science is associated with higher levels of CK and PCK.

4.9.1.2 Correlations between OTL school physical science and PSTs' knowledge (CK and PCK)

Table 4.77 presents the range of the correlation coefficients between OTL school-level physical science and knowledge (CK and PCK) mean scores. The range of the coefficients is as follows: CK (0.10 < r < 0.37) and PCK (-0.01 < r < 0.36).

Table 4.77: Correlations between OTL school-level physical science and PSTs' CK and PCK

	Content knowledge		Pedagogical content knowledge	
Code	r	p-value	r	p-value
OTL2A	0.20*	0.04	0.15	0.11
OTL2B	0.26**	0.01	0.17	0.07
OTL2C	0.18	0.06	0.20*	0.03
OTL2D	0.22*	0.02	0.08	0.38
OTL2E	0.11	0.24	0.03	0.72
OTL2F	0.24*	0.01	0.10	0.30
OTL2G	0.32**	0.00	0.24*	0.01
OTL2H	0.34**	0.00	0.28**	0.00
OTL2I	0.27**	0.00	0.23*	0.02
OTL2J	0.37**	0.00	0.36**	0.00
OTL2K	0.28**	0.00	0.20*	0.03
OTL2L	0.15	0.13	0.11	0.23
OTL2M	0.21*	0.03	-0.01	0.91
OTL2N	0.15	0.10	0.00	0.99
OTL2O	0.26**	0.01	0.15	0.11
OTL2P	0.17	0.07	0.17	0.07
OTL2Q	0.14	0.14	-0.01	0.88
OTL2R	0.27**	0.00	0.17	0.07
OTL2S	0.21*	0.02	0.15	0.12
OTL2T	0.25**	0.01	0.12	0.21
OTL2U	0.10	0.31	0.11	0.23

**r significant at p < 0.05 and **r significant at p < 0.01*

Correlations between OTL school-level physical science and CK show that all the correlation coefficients are positive but weak. There are also more significant correlation coefficients between OTL school-level physical science topics and CK than non-significant ones. The findings therefore suggest OTL tertiary and school-level science have positive associations with PSTs' CK. A somewhat similar trend is observed for correlations between OTL school-level physical science and PCK where there are weak positive and negative correlation coefficients, although there are more positive correlation coefficients than negative ones (2 negative correlation coefficients). The findings therefore indicate that there are positive but weak association between OTL school-level physical science and PSTs PCK.

4.9.1.3 Correlations between OTL physical science pedagogy and PSTs' knowledge (CK and PCK)

Table 4.78 presents the range of the correlation coefficients between OTL physical science pedagogy and knowledge (CK and PCK) mean scores. The range of the coefficients is as follows: CK (-0.25 < r < 0.34) and PCK (-0.15 < r < 0.36).

Table 4.78: Correlations between OTL physical science pedagogy and PSTs' CK and PCK

	Content knowledge		Pedagogical content knowledge	
Code	r	p-value	r	p-value
OTL6A	-0.10	0.27	0.02	0.87
OTL6B	-0.15	0.13	0.00	0.97
OTL6C	-0.10	0.30	-0.01	0.88
OTL6D	0.34**	0.00	0.26**	0.01
OTL6E	-0.25**	0.01	-0.15	0.11
OTL6F	-0.14	0.15	-0.02	0.84
OTL6G	-0.12	0.22	-0.14	0.15
OTL6H	-0.19*	0.04	-0.14	0.15
OTL6I	0.02	0.84	0.07	0.47
OTL6J	-0.09	0.34	0.03	0.73

**r significant at p < 0.05 and **r significant at p < 0.01*

The correlations of OTL physical science pedagogy and CK illustrate that most of the correlations have weak but negative correlation coefficients, with few positive and negative significant correlation coefficients. The correlation coefficients of OTL physical science pedagogy and PCK illustrate that there are equal numbers of negative and positive correlations, with few positive significant correlation coefficients. The finding suggests that OTL physical science pedagogy have negative associations with CK, but the relationship is not clear for OTL physical science pedagogy and PCK.

4.9.1.4 Correlations between OTL through reflection and PSTs' knowledge (CK and PCK)

Table 4.79 presents the range of the correlation coefficients between OTL through reflection and knowledge (CK and PCK) scores. The range of the coefficients is as follows: CK ($-0.17 < r < 0.01$) and PCK ($-0.09 < r < 0.05$).

Table 4.79: Correlations between OTL through reflection and PSTs' CK and PCK

	Content knowledge		Pedagogical content knowledge	
Code	r	p-value	r	p-value
OTL9A	-0.09	0.33	0.00	0.98
OTL9B	-0.15	0.12	-0.05	0.60
OTL9C	-0.15	0.10	-0.08	0.39
OTL9D	0.01	0.96	0.05	0.57
OTL9E	-0.07	0.47	-0.01	0.88
OTL9F	-0.10	0.28	-0.06	0.55
OTL9G	-0.15	0.11	0.03	0.72
OTL9H	-0.17	0.08	-0.05	0.59
OTL9I	-0.16	0.10	-0.09	0.36

**r significant at $p < 0.05$ and **r significant at $p < 0.01$*

The correlations of OTL through reflection and CK illustrate that most of the correlations have weak but negative correlation coefficients with no significant correlation coefficients. The correlation coefficients of OTL through reflection and PCK illustrate that most of the correlations have weak but negative correlation coefficients with no significant correlation coefficients. The findings therefore suggest that OTL through reflection and knowledge scores have negative but weak associations.

4.9.1.5 Correlations between OTL through teaching practice and PSTs' knowledge (CK and PCK)

Table 4.80 presents the range of the correlation coefficients for the time that is spent teaching and with a mentor present, and knowledge (CK and PCK) scores. The range of the coefficients is as follows: CK (r = -0.05 and r = 0.11) and PCK (r = 0.12 and r = 0.29).

Table 4.80 Correlations between time spent teaching during teaching practice and PSTs' CK and PCK

	Content knowledge		Pedagogical content knowledge	
Code	r	p-value	r	p-value
OTL11	-0.05	0.63	0.12	0.20
OTL12	0.11	0.27	0.29**	0.00

**r significant at p < 0.05 and **r significant at p < 0.01*

Table 4.81 presents the range of the correlation coefficients between OTL through teaching practice and knowledge (CK and PCK) scores. The range of the coefficients is as follows: CK (-0.18 < r < 0.56) and PCK (-0.12 < r < 0.31).

Table 4.81 Correlations between OTL through teaching practice and PSTs' CK and PCK

	Content knowledge		Pedagogical content knowledge	
Code	r	p-value	r	p-value
OTL14A	-0.18	0.06	-0.12	0.19
OTL14B	-0.03	0.77	-0.05	0.62
OTL14C	-0.17	0.08	0.02	0.86
OTL14D	-0.12	0.19	-0.05	0.62
OTL14E	-0.18	0.06	-0.08	0.38
OTL14F	-0.18	0.05	-0.04	0.64
OTL14G	0.56**	0.00	0.27**	0.00
OTL14H	0.53**	0.00	0.31**	0.00

**r significant at p < 0.05 and **r significant at p < 0.01*

The correlations of OTL through teaching practice and CK illustrate that most of the correlations have weak but negative correlation coefficients with few positive and negative significant correlation coefficients. Consuegra *et al* (2014) also found that, similar to the present study' findings, field placements did not affect PSTs' subject matter expertise. However, moderate correlation coefficients ($r = 0.56$ and $r = 0.53$) are observed for CK and items that deal with similarities between methods that are used in schools and those that PSTs are exposed to in their teacher education programmes. The correlation coefficients of OTL through teaching practice and PCK illustrate that most of the correlations have weak but negative correlation coefficients, with few positive and negative significant correlation coefficients. Interestingly, weak but positive significant correlation coefficients ($r = 0.27$ and 0.31) are observed for items in the OTL through teaching practice that deal with the similarities between methods that are used in schools and those that the PSTs learn in their teacher education programmes. The findings suggest that while most of the correlation coefficients are negative but weak, the relative strength of the significant correlation coefficients suggests that there may be positive associations between OTL through teaching practice and knowledge scores.

4.9.1.6 Correlations between OTL in a coherent teacher education programme and PSTs' knowledge (CK and PCK)

Table 4.82 presents the range of the correlation coefficients between OTL in a coherent teacher education programme and knowledge (CK and PCK) scores. The range of the coefficients is as follows: CK ($-0.24 < r < 0.01$) and PCK ($-0.11 < r < 0.07$).

Table 4.82: Correlations between OTL in a coherent teacher education programme and PSTs' CK and PCK

	Content knowledge		Pedagogical content knowledge	
Code	r	p-value	r	p-value
OTL15A	0.01	0.95	-0.01	0.93
OTL15B	-0.24**	0.01	-0.11	0.24
OTL15C	-0.10	0.29	-0.02	0.86
OTL15D	-0.08	0.42	0.09	0.35
OTL15E	-0.02	0.81	0.07	0.45
OTL15F	-0.02	0.85	-0.01	0.94

**r significant at p < 0.05 and **r significant at p < 0.01*

The correlation coefficients of OTL in a coherent programme and CK illustrate that most of the correlations have weak but negative correlation coefficients with one negative significant correlation coefficient. The correlation coefficients of OTL in a coherent programme and PCK illustrate that most of the correlations have weak but negative correlation coefficients with no significant correlation coefficient. The findings therefore suggest that OTL in a coherent programme and knowledge scores have negative but weak associations.

4.9.2 Correlations for the beliefs construct

Correlations between the belief bundles construct and OTL variables are presented below.

4.9.2.1 Correlations between OTL tertiary-level physics and chemistry PSTs' beliefs

Table 4.83 presents the range of the correlation coefficients between OTL tertiary-level physics and the respective belief bundles. The range of the coefficients is as follows: beliefs about the nature of science ($-0.04 < r < 0.31$), beliefs about learning science ($0.08 < r < 0.38$), beliefs about science achievement ($0.08 < r < 0.36$), beliefs about preparedness for teaching ($-0.14 < r < 0.08$), and beliefs about programme effectiveness ($-0.13 < r < 0.13$).

Table 4.83: Correlations between OTL tertiary-level physics and PSTs' beliefs

	Nature of science		Science learning		Science achievement		Preparedness for teaching		Programme effectiveness	
Code	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
OTLP1A	0.24*	0.01	0.09	0.34	0.17	0.08	-0.08	0.38	-0.06	0.55
OTLP1B	0.26**	0.01	0.23*	0.01	0.10	0.31	0.03	0.71	0.05	0.62
OTLP1C	0.17	0.07	0.18	0.06	0.15	0.12	-0.05	0.58	-0.07	0.47
OTLP1D	0.17	0.07	0.17	0.07	0.15	0.10	-0.01	0.92	-0.03	0.75
OTLP1E	0.26**	0.01	0.24*	0.01	0.21*	0.03	-0.13	0.19	-0.09	0.36
OTLP1F	0.25**	0.01	0.28**	0.00	0.19*	0.04	-0.16	0.10	-0.12	0.21
OTLP1G	0.15	0.11	0.17	0.08	0.18	0.06	-0.10	0.28	-0.10	0.31
OTLP1H	0.22*	0.02	0.23*	0.02	0.16	0.10	0.01	0.89	0.09	0.36
OTLP1I	0.31**	0.00	0.27**	0.00	0.30**	0.00	0.00	0.97	0.01	0.95
OTLP1J	0.21*	0.03	0.24*	0.01	0.16	0.09	0.01	0.88	-0.03	0.79
OTLP1K	0.18	0.06	0.13	0.16	0.22*	0.02	-0.04	0.68	-0.03	0.71
OTLP1L	-0.04	0.70	0.08	0.39	0.01	0.94	0.03	0.72	-0.01	0.92
OTLP1M	0.23*	0.02	0.21*	0.02	0.18	0.06	-0.01	0.92	0.02	0.84
OTLP1N	0.25**	0.01	0.38**	0.00	0.36**	0.00	0.09	0.33	0.13	0.16
OTLP1O	0.23*	0.02	0.29**	0.00	0.23*	0.01	-0.04	0.66	-0.06	0.53
OTLP1P	0.14	0.14	0.20*	0.04	0.07	0.48	-0.08	0.42	-0.02	0.80
OTLP1Q	0.22*	0.02	0.29**	0.00	0.19*	0.04	0.06	0.55	0.08	0.42
OTLP1R	0.19	0.05	0.27**	0.00	0.25**	0.01	-0.13	0.16	-0.12	0.20
OTLP1S	0.19*	0.05	0.22*	0.02	0.21*	0.02	-0.14	0.14	-0.13	0.16
OTLP1T	0.13	0.18	0.14	0.14	0.26**	0.01	-0.05	0.62	-0.01	0.90

**r significant at $p < 0.05$ and **r significant at $p < 0.01$*

Table 4.84: Correlations between OTL tertiary-level chemistry and PSTs' beliefs

	Nature of science		Science learning		Science achievement		Preparedness for teaching		Programme effectiveness	
Code	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
OTLC1A	0.24*	0.01	0.30**	0.00	0.21*	0.02	0.11	0.26	0.08	0.43
OTLC1B	0.26**	0.01	0.28**	0.00	0.17	0.08	0.14	0.16	0.12	0.20
OTLC1C	0.14	0.14	0.17	0.07	0.09	0.34	0.16	0.10	0.21*	0.03
OTLC1D	0.17	0.07	0.19	0.05	0.19*	0.05	-0.03	0.75	0.00	0.97
OTLC1E	0.21*	0.02	0.20*	0.03	0.08	0.42	0.18	0.05	0.20*	0.03
OTLC1F	0.03	0.74	0.26**	0.01	0.08	0.40	0.02	0.85	0.01	0.95
OTLC1G	0.13	0.16	0.18	0.06	0.04	0.69	0.14	0.14	0.14	0.14
OTLC1H	0.27**	0.00	0.27**	0.00	0.14	0.13	0.06	0.50	0.15	0.10
OTLC1I	0.17	0.07	0.24*	0.01	0.21*	0.03	0.09	0.35	0.08	0.43
OTLC1J	0.17	0.07	0.20*	0.04	0.09	0.33	0.15	0.11	0.22*	0.02
OTLC1K	0.16	0.09	0.17	0.08	0.15	0.12	-0.05	0.63	0.01	0.90
OTLC1L	0.26**	0.01	0.16	0.09	0.12	0.21	0.15	0.11	0.17	0.08
OTLC1M	0.24*	0.01	0.26**	0.01	0.18	0.06	0.14	0.14	0.21*	0.02

OTLC1N	0.20*	0.04	0.29**	0.00	0.10	0.27	0.16	0.10	0.17	0.08
OTLC1O	0.31**	0.00	0.18	0.05	0.24**	0.01	0.00	0.96	0.02	0.83
OTLC1P	0.12	0.19	0.18	0.05	0.20*	0.03	0.02	0.83	0.08	0.37
OTLC1Q	0.27**	0.00	0.14	0.16	0.15	0.12	0.00	1.00	0.12	0.20
OTLC1R	0.25**	0.01	0.27**	0.00	0.32**	0.00	-0.16	0.08	-0.01	0.93
OTLC1S	-0.04	0.67	0.06	0.53	0.01	0.89	0.11	0.24	0.15	0.11
OTLC1T	0.20*	0.04	0.21*	0.03	0.35**	0.00	-0.13	0.16	-0.13	0.18

**r significant at $p < 0.05$ and **r significant at $p < 0.01$*

Table 4.84 presents the range of the correlation coefficients between OTL tertiary-level chemistry and the respective belief bundles. The range of the coefficients is as follows: beliefs about the nature of science ($-0.04 < r < 0.31$), beliefs about learning science ($0.06 < r < 0.30$), beliefs about science achievement ($0.01 < r < 0.35$), beliefs about preparedness for teaching ($-0.16 < r < 0.18$), and beliefs about programme effectiveness ($-0.13 < r < 0.22$).

The correlations of the OTL tertiary-level physics and chemistry, and beliefs about the nature of science, learning science and science achievement mean scores reveal that there are mostly positive but weak associations between the variables. The correlation coefficients of the OTL tertiary-level physics and chemistry, and beliefs about preparedness for teaching mean scores reveal that there are negative and positive but weak correlation coefficients for the OTL. This finding mirrors Tillotson and Young's (2013) finding where they report that the PSTs in their study believe that CK modules did very little in terms of preparing them to be effective teachers. The correlation coefficients of the OTL tertiary-level physics and chemistry, and beliefs about programme effectiveness mean scores reveal that there are negative and positive but weak correlation coefficients for the OTL. An interesting observation is that OTL physics and beliefs about preparedness for teaching and programme effectiveness have significantly more negative correlation coefficients than OTL chemistry and the same beliefs. The findings therefore suggest that OTL tertiary physics and chemistry, and beliefs about nature of science, learning science and science achievement have positive but weak associations but no clear trend can be deduced for beliefs about preparedness for teaching and programme effectiveness.

4.9.2.3 Correlations between OTL school physical science and PSTs' beliefs

Table 4.85 presents the range of the correlation coefficients between OTL school-level physical science and the respective belief bundles. The range of the coefficients is as follows: beliefs about the nature of science ($0.06 < r < 0.27$), beliefs about learning science ($0.06 < r < 0.37$), beliefs about science achievement ($0.12 < r < 0.44$), beliefs about preparedness for teaching ($-0.21 < r < 0.09$), and beliefs about programme effectiveness ($-0.09 < r < 0.18$).

Table 4.85: Correlations between OTL school physical science and PSTs' beliefs

	Nature of science		Science learning		Science achievement		Preparedness for teaching		Programme effectiveness	
Code	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
OTL2A	0.10	0.29	0.22*	0.02	0.19*	0.05	-0.06	0.56	0.02	0.85
OTL2B	0.20*	0.04	0.30**	0.00	0.26**	0.00	-0.02	0.80	0.06	0.55
OTL2C	0.13	0.16	0.23*	0.01	0.21*	0.02	-0.03	0.74	0.04	0.67
OTL2D	0.17	0.07	0.24*	0.01	0.26**	0.00	-0.07	0.46	-0.02	0.86
OTL2E	0.10	0.30	0.16	0.10	0.13	0.16	-0.14	0.15	-0.07	0.48
OTL2F	0.18	0.06	0.23*	0.01	0.25**	0.01	-0.12	0.21	-0.06	0.55
OTL2G	0.26**	0.01	0.32**	0.00	0.33**	0.00	-0.13	0.17	-0.02	0.85
OTL2H	0.23*	0.02	0.26**	0.01	0.39**	0.00	-0.13	0.18	-0.02	0.82
OTL2I	0.23*	0.02	0.29**	0.00	0.31**	0.00	-0.04	0.69	0.02	0.82
OTL2J	0.26**	0.01	0.30**	0.00	0.44**	0.00	-0.09	0.34	-0.03	0.73
OTL2K	0.21*	0.03	0.23*	0.01	0.33**	0.00	-0.08	0.38	-0.05	0.61
OTL2L	0.09	0.37	0.06	0.52	0.27**	0.00	-0.12	0.22	-0.07	0.44
OTL2M	0.06	0.51	0.17	0.08	0.27**	0.00	-0.11	0.26	-0.08	0.40
OTL2N	0.08	0.40	0.16	0.10	0.17	0.07	-0.13	0.19	-0.09	0.35
OTL2O	0.18	0.05	0.25**	0.01	0.28**	0.00	-0.11	0.26	-0.08	0.39
OTL2P	0.19*	0.04	0.30**	0.00	0.20*	0.04	-0.21*	0.03	-0.06	0.52
OTL2Q	0.07	0.48	0.16	0.09	0.12	0.20	-0.12	0.20	-0.08	0.42
OTL2R	0.23*	0.01	0.37**	0.00	0.28**	0.00	-0.07	0.44	0.07	0.47
OTL2S	0.15	0.11	0.19*	0.04	0.22*	0.02	-0.08	0.40	0.01	0.93
OTL2T	0.27**	0.00	0.27**	0.00	0.27**	0.00	0.04	0.65	0.11	0.25
OTL2U	0.20*	0.04	0.29**	0.00	0.17	0.08	0.09	0.37	0.18	0.06

**r significant at $p < 0.05$ and **r significant at $p < 0.01$*

Correlations between OTL school-level physical science and beliefs about the nature of science, learning science and science achievement show that there are weak but positive associations between the said variables. Anderson *et al* (2000) and Tanase and Wang's (2010) findings are similar to the present study's findings, because the data suggest that interaction with science-related courses may help change PSTs' beliefs and they may have enhanced appreciation of learner-centred approaches. Correlation coefficients between OTL school-level physical science and beliefs about preparedness for teaching and programme effectiveness show that there are weak but mostly negative associations between the variables. The findings therefore suggest that OTL school-level physical science and beliefs about nature of science, learning science and science achievement have positive but weak associations and there are negative associations between OTL school-level physical science and beliefs about preparedness for teaching and programme effectiveness.

4.9.2.4 Correlation coefficients between OTL physical science pedagogy and PSTs' beliefs

Table 4.86 presents the range of the correlation coefficients between OTL physical science pedagogy and the respective belief bundles. The range of the coefficients is as follows: beliefs about the nature of science ($-0.05 < r < 0.33$), beliefs about learning science ($0.05 < r < 0.31$), beliefs about science achievement ($-0.15 < r < 0.31$), beliefs about preparedness for teaching ($0.05 < r < 0.66$), and beliefs about programme effectiveness ($0.15 < r < 0.67$).

Table 4.86: Correlations between OTL physical science pedagogy and PSTs' beliefs

	Nature of science		Science learning		Science achievement		Preparedness for teaching		Programme effectiveness	
Code	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
OTL6A	0.14	0.14	0.19*	0.04	-0.02	0.85	0.52**	0.00	0.56**	0.00
OTL6B	0.15	0.11	0.17	0.08	-0.07	0.45	0.55**	0.00	0.55**	0.00
OTL6C	0.23*	0.01	0.31**	0.00	-0.03	0.75	0.61**	0.00	0.56**	0.00
OTL6D	0.33**	0.00	0.23*	0.02	0.31**	0.00	0.05	0.60	0.15	0.12
OTL6E	-0.05	0.60	0.05	0.61	-0.27**	0.00	0.59**	0.00	0.48**	0.00
OTL6F	0.15	0.10	0.13	0.17	-0.07	0.44	0.60**	0.00	0.59**	0.00
OTL6G	0.11	0.24	0.16	0.10	-0.15	0.12	0.66**	0.00	0.63**	0.00
OTL6H	0.13	0.18	0.19*	0.05	-0.07	0.44	0.55**	0.00	0.54**	0.00
OTL6I	0.30**	0.00	0.26**	0.01	0.01	0.92	0.56**	0.00	0.51**	0.00
OTL6J	0.15	0.13	0.25**	0.01	-0.09	0.32	0.64**	0.00	0.67**	0.00

**r significant at $p < 0.05$ and **r significant at $p < 0.01$*

The correlations of OTL physical science pedagogy and beliefs about the nature of science and learning science illustrate that most of the correlation coefficients are positive but weak, with a fair number of positive significant correlation coefficients. Similarly, Tatar (2015) found that PSTs tend to hold desirable beliefs about the nature of science if they have the OTL science pedagogy. Roychoudhury and Rice (2013) also found that, similar to the present study's findings, content-focused courses such as science pedagogy courses may help PSTs to accommodate diverse learner abilities. The correlation coefficients of OTL physical science pedagogy and beliefs about science achievement illustrate that most of the correlations have negative but weak correlations with one positive and one negative significant correlation coefficients. The correlation coefficients between OTL physical science pedagogy and beliefs about preparedness for teaching and programme effectiveness illustrate that most of the correlations have strong positive correlations with numerous positive significant correlation coefficients. The findings therefore suggest that OTL physical science pedagogy and beliefs about nature of science and learning science have positive but weak associations and there are negative associations between OTL physical science pedagogy and beliefs about science achievement. The correlation coefficients between OTL physical science pedagogy and beliefs about preparedness for teaching and programme effectiveness, on the other hand, illustrate that there are strong association between the said variables.

4.9.2.5 Correlations between OTL through reflection and PSTs' beliefs

Table 4.87 presents the range of the correlation coefficients between OTL through reflection and the respective belief bundles. The range of the coefficients is as follows: beliefs about the nature of science ($0.04 < r < 0.27$), beliefs about learning science ($0.10 < r < 0.34$), beliefs about science achievement ($-0.14 < r < -0.04$), beliefs about preparedness for teaching ($0.38 < r < 0.66$), and beliefs about programme effectiveness ($0.43 < r < 0.70$).

Table 4.87: Correlations between OTL through reflection and PSTs' beliefs

	Nature of science		Science learning		Science achievement		Preparedness for teaching		Programme effectiveness	
Code	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
OTL9A	0.09	0.36	0.17	0.08	-0.11	0.24	0.53**	0.00	0.57**	0.00
OTL9B	0.06	0.53	0.19*	0.04	-0.14	0.14	0.46**	0.00	0.43**	0.00
OTL9C	0.05	0.63	0.22*	0.02	-0.08	0.39	0.38**	0.00	0.44**	0.00
OTL9D	0.27**	0.00	0.34**	0.00	-0.04	0.70	0.66**	0.00	0.70**	0.00
OTL9E	0.17	0.07	0.23*	0.02	-0.10	0.27	0.54**	0.00	0.61**	0.00
OTL9F	0.08	0.39	0.10	0.29	-0.12	0.21	0.50**	0.00	0.56**	0.00
OTL9G	0.06	0.51	0.14	0.13	-0.14	0.14	0.52**	0.00	0.53**	0.00
OTL9H	0.08	0.39	0.20*	0.04	-0.11	0.26	0.53**	0.00	0.58**	0.00
OTL9I	0.04	0.68	0.16	0.10	-0.10	0.31	0.54**	0.00	0.52**	0.00

**r significant at p < 0.05 and **r significant at p < 0.01*

The correlation coefficients of OTL through reflection and beliefs about the nature of science and learning science illustrate that most of the correlations are positive but weak, with a fair number of positive significant correlation coefficients. The correlation coefficients of OTL through reflection and beliefs about science achievement illustrate that all the correlations have weak but negative correlations, with no significant correlation coefficients. The correlation coefficients of OTL through reflection and beliefs about preparedness for teaching physical science and programme effectiveness illustrate that most of the correlations have moderately strong positive correlations, with numerous positively significant correlation coefficients. The findings therefore suggest that OTL through reflection and beliefs about nature of science and learning science, have positive but weak associations and there are negative associations between OTL through reflection and beliefs about science achievement. The correlation coefficients between OTL through reflection and beliefs about preparedness for teaching and programme effectiveness, on the other hand, illustrate that there are strong associations between the said variables.

4.9.2.6 Correlations between OTL through teaching practice and PSTs' beliefs

Table 4.88 presents correlation coefficients between time spent teaching and with a mentor present, and the respective belief bundles. The coefficients are as follows: beliefs about the nature of science (r = 0.18 and r = 0.25, respectively), beliefs about learning science (r = 0.29 & r = 0.42, respectively), beliefs about science achievement (r = -0.04 & r = 0.11, respectively), beliefs about preparedness for teaching (r = 0.49 & r = 0.54, respectively), and beliefs about programme effectiveness (r = 0.48 & r = 0.53, respectively).

Table 4.88: Correlations between teaching time and mentor presence and PSTs' beliefs

	Nature of science		Science learning		Science achievement		Preparedness for teaching		Programme effectiveness	
Code	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
OTL11	0.18	0.06	0.29**	0.00	-0.04	0.65	0.49**	0.00	0.48**	0.00
OTL12	0.25**	0.01	0.42**	0.00	0.11	0.23	0.54**	0.00	0.53**	0.00

**r significant at p < 0.05 and **r significant at p < 0.01*

Correlation coefficients of time spent teaching and with a mentor present, and beliefs about the nature of science and science learning illustrate that there are positive but weak associations between the variables. Correlation coefficients of time spent teaching and with a mentor present, and beliefs about science achievement do not show any prominent trends. Correlation coefficients of time spent teaching and with a mentor present, and beliefs about the preparedness for teaching physical science and programme effectiveness illustrate that there are positive and moderately strong associations between the variables.

Table 4.89 presents the range of the correlation coefficients between OTL through teaching practice and the respective belief bundles. The range of the coefficients is as follows: beliefs about the nature of science (-0.04 < r < 0.73), beliefs about learning science (-0.01 < r < 0.48), beliefs about science achievement (-0.07 < r < 0.56), beliefs about preparedness for teaching (0.16 < r < 0.66), and beliefs about programme effectiveness (0.17 < r < 0.62).

Table 4.89: Correlations between OTL through teaching practice and PSTs' beliefs

	Nature of science		Science learning		Science achievement		Preparedness for teaching		Programme effectiveness	
Code	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
OTL14A	-0.01	0.91	0.08	0.39	-0.24*	0.01	0.66**	0.00	0.61**	0.00
OTL14B	0.18	0.05	0.23*	0.01	-0.07	0.48	0.62**	0.00	0.62**	0.00
OTL14C	0.07	0.45	0.21*	0.03	-0.14	0.13	0.61**	0.00	0.55**	0.00
OTL14D	0.12	0.2	0.23*	0.01	-0.13	0.18	0.52**	0.00	0.60**	0.00
OTL14E	-0.04	0.67	-0.01	0.96	-0.23**	0.00	0.55**	0.00	0.44**	0.00
OTL14F	0.07	0.46	0.18	0.05	-0.18	0.06	0.56**	0.00	0.53**	0.00
OTL14G	0.68**	0.00	0.48**	0.00	0.51**	0.00	0.16	0.08	0.17	0.07
OTL14H	0.73**	0.00	0.48**	0.00	0.56**	0.00	0.18	0.06	0.25**	0.01

**r significant at p < 0.05 and **r significant at p < 0.01*

The correlations of OTL through teaching practice and beliefs about the nature of science illustrate that most of the correlation coefficients are positive but weak, with a fair number of positive significant correlation coefficients. The findings are, however, not in agreement with Boz and Uzuntiryaki's (2006) findings where they discovered that PSTs in their study did not develop constructivist-orientated beliefs resulting from their participation in teaching practice. Similarities between teaching methods that PSTs and supervising teachers use and those that PSTs learn in their programmes have moderately high correlation coefficients (r = 0.68 and r = 0.73), indicating that there are strong associations between the items and beliefs about the nature of science. The correlation coefficients of OTL through teaching practice and beliefs about learning science illustrate that most of the correlations have weak but positive correlations, with a fair number of positive significant correlation coefficients. The correlation coefficients of OTL through teaching practice and beliefs about science achievement illustrate that most of the correlations have weak but negative correlations, with few positive and negative significant correlation coefficients. However, moderately large correlation coefficients (r = 0.51 and r = 0.56) are observed for items in the OTL learn through teaching practice that deal with the similarities between methods used in schools and those that the PSTs learn in their teacher education programmes. The correlation coefficients of OTL through teaching practice and beliefs about preparedness for teaching physical science and programme effectiveness illustrate that most of the correlations have moderately strong positive correlations with numerous positive significant correlation coefficients. The findings therefore suggest that OTL through teaching practice and beliefs about the nature of science and learning science have positive but weak associations and there are negative associations between OTL through teaching practice and beliefs about science achievement. The correlation coefficients between OTL through teaching practice and beliefs about preparedness for teaching and programme effectiveness illustrate that there is a strong association between the said variables.

4.9.2.7 Correlations between OTL in a coherent programme and PSTs' beliefs

Table 4.90 presents the range of the correlation coefficients between OTL in a coherent teacher education programme and the respective belief bundles. The range of the coefficients is as follows: beliefs about the nature of science ($0.1 < r < 0.25$), beliefs about learning science ($0.13 < r < 0.29$), beliefs about science achievement ($-0.22 < r < 0.02$), beliefs about preparedness for teaching ($0.46 < r < 0.70$), and beliefs about programme effectiveness ($0.54 < r < 0.66$).

Table 4.90: Correlations between OTL in coherent programme and PSTs' beliefs

	Nature of science		Science learning		Science achievement		Preparedness for teaching		Programme effectiveness	
Code	r	p-value	r	p-value	r	p-value	r	p-value	r	p-value
OTL15A	0.18	0.05	0.26**	0.01	0.02	0.87	0.51**	0.00	0.56**	0.00
OTL15B	0.10	0.28	0.13	0.18	-0.22*	0.02	0.70**	0.00	0.64**	0.00
OTL15C	0.19*	0.04	0.18	0.06	-0.13	0.18	0.61**	0.00	0.66**	0.00
OTL15D	0.18	0.05	0.22*	0.02	-0.09	0.33	0.46**	0.00	0.56**	0.00
OTL15E	0.24**	0.01	0.26**	0.01	-0.06	0.53	0.54**	0.00	0.54**	0.00
OTL15F	0.25**	0.01	0.29**	0'00	-0.03	0.74	0.59**	0.00	0.57**	0.00

**r significant at p < 0.05 and **r significant at p < 0.01*

The correlations of OTL in a coherent teacher education programme and beliefs about the nature of science and learning science illustrate that most of the correlation coefficients are positive but weak, with a fair number of positive, significant correlation coefficients. The correlation coefficients of OTL in a coherent teacher education programme and beliefs about science achievement illustrate that most of the correlations have weak but negative correlations, with one negative significant correlation coefficient. The correlation coefficients of OTL through teaching practice and beliefs about preparedness for teaching physical science and programme effectiveness illustrate that most of the correlations have moderately strong positive correlations, with numerous positive significant correlation coefficients. The findings therefore suggest that OTL in a coherent teacher education programme and beliefs about nature of science and learning science have positive but weak associations and there are negative associations between OTL in a coherent teacher education programme and beliefs about science achievement. The correlation coefficients between OTL in a coherent teacher education programme and beliefs about preparedness for teaching and programme effectiveness illustrate that there is a strong association between the said variables.

4.10 Research question five

Which OTL are significant predictors of multiple variables in the knowledge and beliefs constructs?

Multiple linear regression is performed to determine which of the OTL explain the variance observed in the knowledge and beliefs mean scores (Foster *et al*., 2015). The knowledge construct consists of CK and PCK, and the beliefs construct consists of beliefs about the nature of science (BLF1), learning science (BLF2), science achievement (BLF3), preparedness for teaching (BLF4) and programme effectiveness (BLF5). This means that seven regression analyses (two for knowledge and five for beliefs) are performed to determine the effects of OTL on each type of knowledge and beliefs.

Stepwise regression methods are preferred, because the main purpose of the study is to determine a set of OTL items that serve as best predictors for the knowledge and beliefs constructs (Hinkle, Wiersma & Jurs, 2003). Standardised beta coefficients are used because they indicate which independent variables are strong predictors of the dependent variables. Squared semi-partial correlations (sr^2) are also calculated, because they provide a unique variance, which is explained by each independent variable.

The general form of the regression equation that is used in the study is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \ldots + \beta_\infty X_\infty$$

where:

Y = calculated value of the dependent variable

β_0 = constant

$\beta_1, \beta_2, \beta_3 \ldots. \beta_\infty$= standardised coefficients which are also known as beta coefficients

$X_1, X_2, X_3 \ldots X_\infty$ = independent variables

This equation is applicable to all the regression models that are generated in this study.

4.10.1 Combination of OTL scales that significantly affect PSTs' content knowledge (CK)

Table 4.91 presents items that predict PSTs' content knowledge. The prediction model contains nine predictors. It is reached in nine steps, with no variables removed. The model is statistically significant, $F(9,102) = 20.08$, p = 0.000, and it accounts for approximately 64% of the variance of CK mean scores ($R^2 = 0.639$, Adjusted $R^2 = 0.607$). CK is primarily predicted by OTL14G ($\beta_1 = 0.497$, p = 0.000), OTLP1N ($\beta_2 = 0.321$, p = 0.001), OTL15B ($\beta_3 = -0.264$, p = 0.001), OTL6D ($\beta_4 = 0.247$, p = 0.000), OTLC1T ($\beta_5 = 0.335$, p = 0.00), OTLC1L ($\beta_6 = -0.189$, p = 0.011), OTLP1O ($\beta_7 = -0.123$, p = 0.076), OTL9C ($\beta_8 = -0.192$, p = 0.007) and OTL9F ($\beta_9 = 0.194$, p = 0.017).

With

OTL14G: The methods of teaching I used in his field experiences are quite different from the methods he learned in his university course.

OTLP1N **Gaussian laws** (flux of electric field, Gauss laws and its applications).

OTL15B* Later courses in the programme built on what is taught in earlier courses in the programme.

OTL6D Assess low−level objectives (factual knowledge, routine procedures and so forth).

OTLC1T **Organic chemistry** (Hydrocarbons, derivatives of hydrocarbons, mechanism, spectroscopy).

OTLC1L* **Rates of reactions** (reaction rates, dependence of the rate of reactions, reaction mechanisms, the rate law, catalysis).

OTLP1O* **Current, resistance and capacitance** (equipotential surfaces, electric current, resistance and resistivity, Ohm's law, semi and super conductors).

OTL9C* Identify appropriate resources needed for teaching.

OTL9F Set appropriately challenging learning expectations for learners.

The regression equation with CK as the dependent variable is as follows:

$$Y = \beta_0 + 0.497X_1 + 0.321X_2 - 0.264X_3 + 0.247X_4 + 0.335X_5 - 0.189X_6 - 0.123X_7 - 0.192X_8 + 0.194X_9$$

Table 4.91: Regression analysis – content knowledge

Coefficients							
Model		Unstandardised Coefficients B	Unstandardised Coefficients Std. Error	Standardised Coefficients Beta	t	Sig.	sr^2
9	(Constant)	0.050	0.088		0.563	0.575	
	OTL14G	0.096	0.012	0.497	7.792	0.000	0.214
	OTLP1N	0.200	0.042	0.321	4.722	0.000	0.079
	OTL15B	-0.056	0.016	-0.264	-3.552	0.001	0.045
	OTL6D	0.060	0.015	0.247	3.955	0.000	0.055
	OTLC1T	0.254	0.057	0.335	4.464	0.000	0.070
	OTLC1L	-0.106	0.041	-0.189	-2.591	0.011	0.024
	OTLP1O	-0.079	0.044	-0.123	-1.792	0.076	0.011
	OTL9C	-0.046	0.017	-0.192	-2.729	0.007	0.026
	OTL9F	0.038	0.016	0.194	2.436	0.017	0.021

a. Dependent Variable: CK. $R^2 = 0.639$, Adjusted $R^2 = 0.607$, *$p < 0.05$
b. sr^2 is the squared semi-partial correlation

Regression analysis reveals that CK scores are primarily predicted by OTL tertiary-level physics and chemistry (OTLP1N, OTLC1T, OTLC1L & OTLP1O), but OTL school-level physical science (OTL2) is not a predictor of CK (Figure 4.1). This finding is similar to Ingvarson *et al*'s (2007) finding that OTL tertiary-level content is a predictor of CK. The OTL using teaching methods in schools that are similar to those that PSTs are exposed to in university courses (OTL14G) is a strong predictor of CK ($\beta_1 = 0.497$, $p = 0.000$). The finding suggests that affording PSTs the opportunity to use methods they learn in their courses may have a positive impact on their CK. Although this is so, it is somewhat surprising that this coherence between theory and practice is a stronger predictor than any of the OTL content is. Sequencing courses such that content taught builds on previously taught content (OTL15B) is a predictor of CK as well, although the beta coefficient is negative, which is in stark difference to what is known from literature about the sequencing of content (Daehler & Shinohara, 2001). The data also suggest that the assessment of low-level objectives (OTL6D) is a predictor of CK. This finding is also surprising, given that conventional logic suggests that this assessment of low-level objectives may not present opportunities for teachers to engage and reflect on complex responses from learners (Wallace & Kang, 2004). Identification of appropriate resources for teaching (OTL9C) and setting appropriately challenging expectations for learners (OTL9F) are predictors of CK, lending support to the earlier assertion that opportunities to reflect on methodological aspects of teaching physical science may affect the PSTs' CK, although reflecting on appropriate resources has a negative beta coefficient ($\beta_8 = -0.192$, $p = 0.007$).

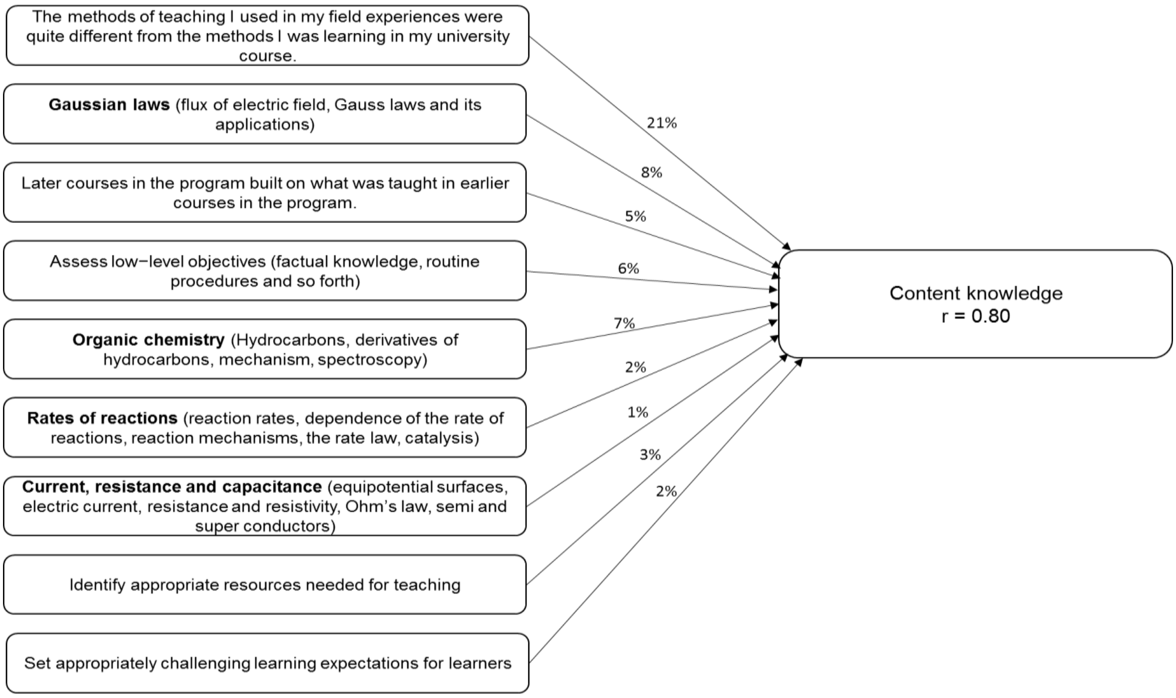


Figure 4.1: Regression analysis with CK as the dependent variable

4.10.2 Combination of OTL scales that significantly affect PSTs' pedagogical content knowledge (PCK)

Table 4.92 presents items that predict PSTs' pedagogical content knowledge. The prediction model contains seven predictors. It is reached in seven steps with no variables removed. The model is statistically significant, $F(7,104) = 10.38$, $p = 0.000$, and it accounts for approximately 41% of the variance of PCK mean scores ($R^2 = 0.411$, Adjusted $R^2 = 0.372$). PCK is primarily predicted by OTL2J ($\beta_1 = 0.484$, $p = 0.000$), OTL2M ($\beta_2 = -0.348$, $p = 0.001$), OTLC1R ($\beta_3 = 0.173$, $p = 0.001$), OTL14H ($\beta_4 = 0.230$, $p = 0.005$), OTLP1M ($\beta_5 = -0.317$, $p = 0.001$), OTLP1S ($\beta_6 = 0.219$, $p = 0.023$), OTL6D ($\beta_7 = 0.167$, $p = 0.043$).

With

OTL2J **Electric circuits and electrodynamics** (emf, potential difference, current, resistance, resistors in parallel and series, electrical machines, alternating current).

OTL2M* **Molecular structure and Intermolecular forces** (a chemical bond; molecular shape; electronegativity and bond polarity, states of matter; density; kinetic energy).

OTLC1R **Nuclear chemistry** (radioactivity and nuclear bombardment reactions, energy of nuclear reactions).

OTL14H The regular supervising teacher in my field experiences classroom taught in ways that were quite different from the methods I was learning in my university course.

OTLP1M* **Electric fields and charges** (field lines, electric fields due to point charges and electric dipoles, electric charges, coulombs law, conservation of charges).

OTLP1S **Atoms and nuclear physics** (properties of atoms, semiconductors, properties of the nucleus, energy form the nucleus).

OTL6D Assess low−level objectives (factual knowledge, routine procedures and so forth).

The regression equation with PCK as the dependent variable is as follows:

$$Y = \beta_0 + 0.484X_1 - 0.348X_2 + 0.173X_3 + 0.230X_4 - 0.317X_5 + 0.219X_6 + 0.167X_7$$

Table 4.92: Regression analysis – Pedagogical Content Knowledge

Coefficients							
		Unstandardised Coefficients		Standardised Coefficients			
Model		B	Std. Error	Beta	t	Sig.	sr^2
7	(Constant)	0.225	0.100		2.240	0.027	
	OTL2J	0.405	0.079	0.484	5.131	0.000	0.149
	OTL2M	-0.291	0.078	-0.348	-3.722	0.000	0.078
	OTLC1R	0.096	0.049	0.173	1.955	0.053	0.022
	OTL14H	0.049	0.017	0.230	2.853	0.005	0.046
	OTLP1M	-0.229	0.067	-0.317	-3.391	0.001	0.065
	OTLP1S	0.149	0.065	0.219	2.306	0.023	0.030
	OTL6D	0.047	0.023	0.167	2.047	0.043	0.024
a. Dependent Variable: PCK. R^2 = 0.411, Adjusted R^2 = 0.372, *p <0.05 b. sr^2 is the square semi-partial correlation							

PCK is predicted by the OTL tertiary (OTLC1R, OTLP1M and OTLP1S) and school-level (OTL2J and OTL2M) science topics as shown in Figure 4.2. This is similar to Ingvarson *et al*'s (2007) findings that content-based courses have a profound effect on teachers' PCK. The use of similar methods by the supervising teachers with those that the PSTs learn in their universities courses (OTL14H) is a predictor of PCK, which suggests that PSTs' PCK may be enhanced when supervising teachers in schools use teaching methods that are similar to those that the PSTs learned in their courses. Assessment of low-level objectives show some effects (OTL6D) and considering that this is the case for CK, it does not come as much of a surprise. This is similar to assertions by Daehler and Shinohara (2001) that PSTs develop their PCK in the methodology/didactics courses. Additionally, the same authors found that the sequencing of content is associated with teachers' pedagogy, but this is not the case according to the present studies' findings.

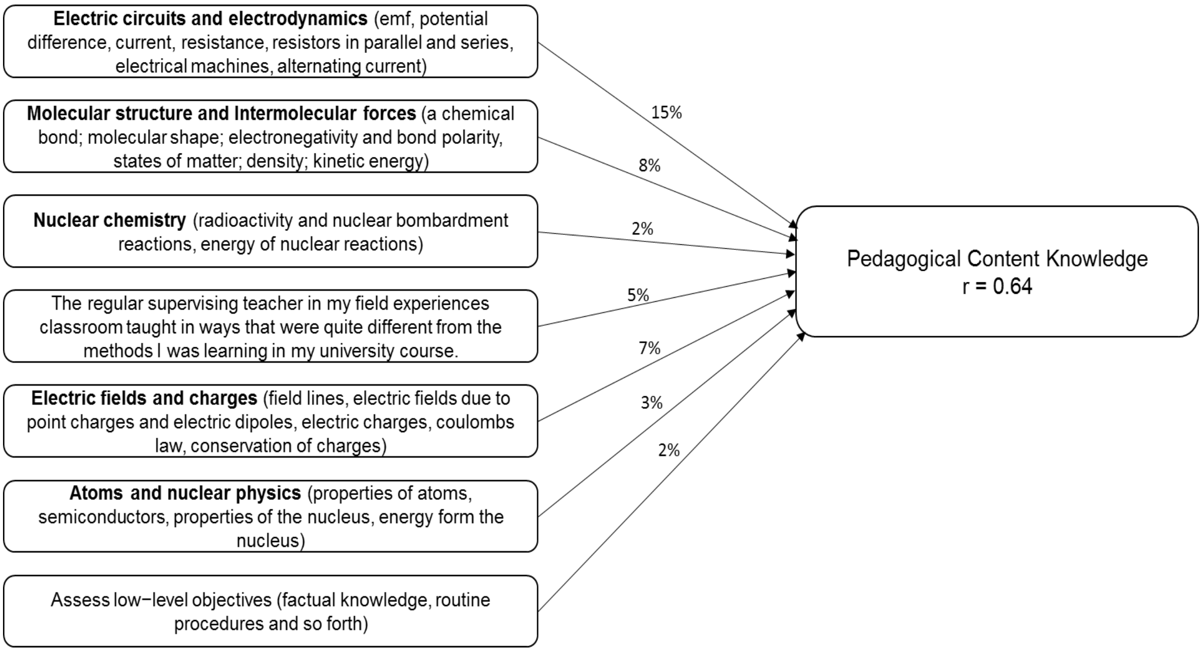


Figure 4.2: Regression analysis with PCK as the dependent variable

4.10.3 Combination of OTL scales that significantly affect PSTs' beliefs about the nature of science (BLF1)

Table 4.93 presents items that predict PSTs' beliefs about the nature of science. The prediction model contains five predictors. It is reached in five steps, with no variables removed. The model is statistically significant, $F(5,106) = 40.50$, $p = 0.000$, and it accounts for approximately 66% of the variance of beliefs about the nature of science mean scores (R^2 = 0.656, Adjusted R^2 = 0.640). Beliefs about the nature of science are primarily predicted by OTL14H (β_1 = 0.432, p = 0.000), OTL14G (β_2 = 0.319, p = 0.000), OTLC1O (β_3 = 0.192, p = 0.001), OTL15F (β_4 = 0.261, p = 0.000), OTL14A (β_5 = -0.177, p = 0.010).

With

OTL14H	The regular supervising teacher in my field experiences classroom taught in ways that were quite different from the methods I was learning in my university course.
OTL14G	The methods of teaching the I used in my field experiences are quite different from the methods I learned in my university course.
OTLC1O	**Acid-base equilibria** (solutions of weak acids and base, solutions of weak acid or base with another solute).
OTL15F	There are clear links between most of the courses in my teacher education programme.
OTL14A*	I had a clear understanding of what my school-based mentor expected of me as a teacher in order to pass the field experiences.

The regression equation with beliefs about the nature of science as the dependent variable is as follows:

$$Y = \beta_0 + 0.432X_1 + 0.319X_2 + 0.192X_3 + 0.261X_4 - 0.177X_5$$

Table 4.93: Regression analysis – beliefs about the nature of science

Coefficients							
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.	sr^2
		B	Std. Error	Beta			
5	(Constant)	1.897	0.251		7.561	0.000	
	OTL14H	0.346	0.069	0.432	4.998	0.000	0.081
	OTL14G	0.270	0.072	0.319	3.734	0.000	0.045
	OTLC1O	0.559	0.169	0.192	3.308	0.001	0.035
	OTL15F	0.244	0.064	0.261	3.811	0.000	0.047
	OTL14A	-0.154	0.059	-0.177	-2.607	0.010	0.022
a. Dependent Variable: BLF1. R^2 =0.656, Adjusted R^2 = 0.0640, *p <0.05 b. sr^2 is the square semi-partial correlation							

The use of similar methods by supervising teachers and those the PSTs learn in their universities courses (OTL14H and OTL14G) are predictors of beliefs about the nature of science as shown in Figure 4.3. This finding further asserts the earlier observation that the link between theory and practice seems to be an important aspect of teacher education. Scholars argue that while PSTs have desirable beliefs with regard to the nature of science, they are unable to teach using the nature of science as a vehicle (Backhus & Thompson, 2006). This finding therefore suggests PSTs' beliefs about the nature of science may be enhanced if mentor teacher and PSTs also use the nature of science as a vehicle to learning science. Indeed, Tillotson and Young (2013) found that PSTs would likely hold desirable beliefs regarding the nature of science if mentor teachers use similar methods to those taught at university when presenting lessons. Koc (2012), on the other hand, showed that PSTs had negative beliefs regarding the nature of science. This was because mentor teachers were not aware of or rarely used inquiry methods in their teaching. Clear expectations about PSTs (OTL14A) show significant effects with regard to beliefs about the nature of science, although the beta coefficient is negative. This may be because it is rare where teacher educators hold workshops for mentor teachers regarding their expectations about the PSTs' performance (Henry *et al.*, 2010). This lack of communication likely leads to differences in the expectations and insecurities on the part of PSTs. Clear links between courses in teacher education programmes (OTL15F) and OTL learn tertiary chemistry (OTLC1O) are also predictors of beliefs about the nature of science. This finding makes sense, because PSTs will hold desirable beliefs about the nature of science if they have the OTL content, and the links between content and pedagogy are made explicit (Tillotson & Young, 2013).

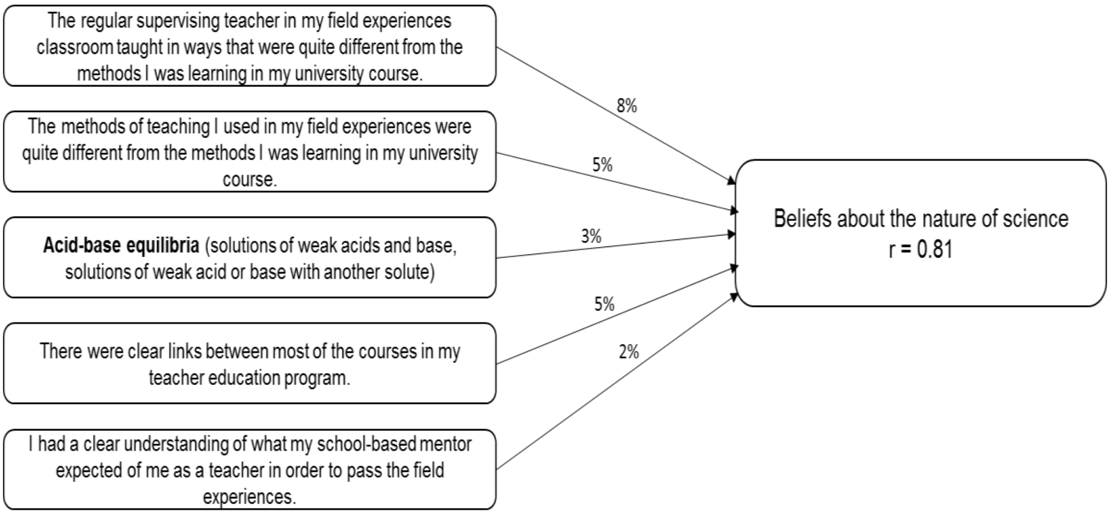


Figure 4.3: Regression analysis with beliefs about the nature of science as the dependent variable

4.10.4 Combination of OTL scales that significantly affect PSTs' beliefs about learning science (BLF2)

Table 4.94 presents items that predict PSTs' beliefs about learning science. The prediction model contains seven predictors. It is reached in seven steps, with no variables removed. The model is statistically significant, $F(6,105) = 17.47$, $p = 0.000$, and it accounts for approximately 50% of the variance of beliefs about learning science mean scores ($R^2 = 0.500$, Adjusted $R^2 = 0.471$). Beliefs about learning science are primarily predicted by OTL14H ($\beta_1 = 0.176$, $p = 0.099$), OTL2R ($\beta_2 = 0.280$, $p = 0.000$), OTL15A ($\beta_3 = 0.155$, $p = 0.050$), OTLP1N ($\beta_4 = 0.269$, $p = 0.000$), OTL14G ($\beta_5 = 0.265$, $p = 0.013$), OTL6J ($\beta_6 = 0.177$, $p = 0.026$).

With

OTL14H	The regular supervising teacher in my field experiences classroom taught in ways that were quite different from the methods I learned in my university course.
OTL2R	**Stoichiometry** (molar volume of gases; concentration; limiting reagents; volume relationships in gaseous reactions).

OTL15A	Each stage of the programme seemed to be planned to meet the main needs I had at that stage of my preparation.
OTLP1N	**Gaussian laws** (flux of electric field, Gauss laws and its applications).
OTL14G	The methods of teaching I used in my field experiences were quite different from the methods I learned learning in my university course.
OTL6J	Integrate physical science ideas from across areas of science.

The regression equation with beliefs about learning science as the dependent variable is as follows:

$$Y = \beta_0 + 0.176X_1 + 0.280X_2 + 0.155X_3 + 0.269X_4 + 0.265X_5 + 0.177$$

Table 4.94: Regression analysis – beliefs about science learning

Coefficients							
Model		Unstandardised Coefficients		Standardised Coefficients	t	Sig.	sr^2
		B	Std. Error	Beta			
6	(Constant)	1.218	0.359		3.392	0.001	
	OTL14H	0.140	0.084	0.176	1.666	0.099	0.013
	OTL2R	0.812	0.208	0.280	3.902	0.000	0.072
	OTL15A	0.167	0.084	0.155	1.983	0.050	0.019
	OTLP1N	0.731	0.196	0.269	3.720	0.000	0.066
	OTL14G	0.224	0.088	0.265	2.533	0.013	0.031
	OTL6J	0.165	0.073	0.177	2.258	0.026	0.024
a. Dependent Variable: BLF2. R^2 = 0.500, Adjusted R^2 = 0.471, *p <0.05 b. sr^2 is the square semi-partial correlation							

Predictors for beliefs about learning science include the use of similar methods by supervising teachers and PSTs when teaching with those the PSTs learned in their university courses (OTL14H and OTL14G) (Figure 4.4). PSTs expect to be exposed to best methods for teaching physical science and if these methods are not applied in practice, they might not develop desirable beliefs about learning science (Sorensen *et al*., 2012). Hancock and Gallard (2004) also mention that PSTs do not develop proper beliefs about learning science, because they get little opportunity to observe teachers modelling reform-based methods and strategies.

Planning that meets the PSTs' needs at certain stages of their preparation (OTL15A) shows significant effects as well. PSTs went through the education system and they experienced success in a system that did not necessarily reflect reform-based methods (Pajares, 1992). It is therefore important to address the undesirable beliefs and, with proper planning of experiences that the PSTs are exposed to, PSTs' beliefs may be altered, even though their beliefs have been shown to be resilient in most cases (Bryan, 2012). The integration of ideas from across areas of science into physical science (OTL6J) also accounts for the variance observed in the beliefs about learning science scores. Finally, OTL tertiary-level physics (OTLP1N) and school-level physical science (OTL2R) show some effects with beliefs about learning science. It is important to have thorough CK and the process that underpins knowledge generation in physical science, as this will allow PSTs to develop an appreciation for the desirable beliefs about learning physical science.

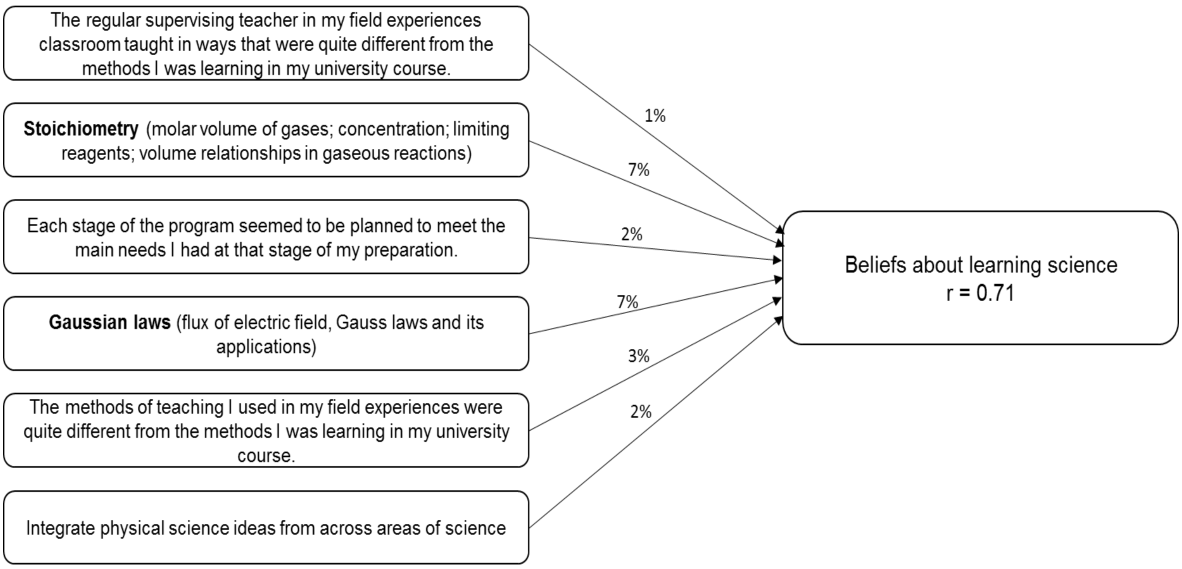


Figure 4.4: Regression analysis with beliefs about learning science as the dependent variable

4.10.5 Combination of OTL scales that significantly affect PSTs' beliefs about science achievement (BLF3)

Table 4.95 presents items that predict PSTs' beliefs about science achievement. The prediction model contains eight predictors. It is reached in eight steps with no variables removed. The model is statistically significant, $F(8,103) = 21.13$, $p = 0.000$, and it accounts for approximately 62% of the variance of beliefs about science achievement mean scores ($R^2 = 0.621$, Adjusted $R^2 = 0.592$). Beliefs about science achievement are primarily predicted by OTL14H ($\beta_1 = 0.319$, $p = 0.001$), OTL2J ($\beta_2 = 0.282$, $p = 0.000$), OTL14E ($\beta_3 = -0.251$, $p = 0.001$), OTL15A ($\beta_4 = 0.205$, $p = 0.005$), OTL15B ($\beta_5 = -0.214$, $p = 0.004$), OTLP1N ($\beta_6 = 0.159$, $p = 0.019$), OTL6D ($\beta_7 = 0.128$, $p = 0.048$), OTL14G ($\beta_8 = 0.184$, $p = 0.049$).

With

OTL14H	The regular supervising teacher in my field experiences classroom taught in ways that were quite different from the methods I learned in my university course.
OTL2J	**Electric circuits and electrodynamics** (emf, potential difference, current, resistance, resistors in parallel and series, electrical machines, alternating current)
OTL14E*	The feedback I received from my mentor helped me to improve my teaching methods.
OTL15A*	Each stage of the programme seemed to be planned to meet the main needs I had at that stage of my preparation.
OTL15B	Later courses in the programme built on what was taught in earlier courses in the programme.
OTLP1N	**Gaussian laws** (flux of electric field, Gauss laws and its applications)
OTL6D	Assess low−level objectives (factual knowledge, routine procedures and so forth).
OTL14G	The methods of teaching I used in my field experiences were quite different from the methods I learned in my university course.

The regression equation with beliefs about science achievement as the dependent variable is as follows

$$Y = \beta_0 + 0.319X_1 + 0.282X_2 - 0.251X_3 + 0.205X_4 - 0.214X_5 + 0.159X_6 + 0.128X_7 + 0.184X_8$$

Table 4.95: Regression analysis – beliefs about science achievement

Coefficients								
Model		Unstandardised Coefficients B	Unstandardised Coefficients Std. Error	Standardised Coefficients Beta	t	Sig.	sr^2
8	(Constant)	2.299	0.460		4.998	0.000	
	OTL14H	0.304	0.090	0.319	3.387	0.001	0.042
	OTL2J	1.063	0.251	0.282	4.240	0.000	0.066
	OTL14E	-0.313	0.091	-0.251	-3.432	0.001	0.043
	OTL15A	0.264	0.093	0.205	2.846	0.005	0.030
	OTL15B	-0.239	0.080	-0.214	-2.988	0.004	0.033
	OTLP1N	0.518	0.216	0.159	2.393	0.019	0.021
	OTL6D	0.161	0.081	0.128	2.000	0.048	0.015
	OTL14G	0.185	0.093	0.184	1.990	0.049	0.015

a. Dependent Variable: BLF3. R^2 = 0.621, Adjusted R^2 = 0.592, *p <0.05
b. sr^2 is the square semi-partial correlation

The use of similar methods by supervising teachers and PSTs when teaching with those the PSTs learned in their universities courses (OTL14H and OTL14G) are predictors of beliefs about science achievement as shown in Figure 4.5. Inclusive education and education for social justice form a critical part of PSTs' training because of an understanding that this knowledge will assist PSTs in dealing with social issues that arise during teaching and learning of physical science. Therefore, the use of methods that are cognisant of gender, ethnicity and language to teach may help improve PSTs' beliefs about science achievement. Feedback received by PSTs from their mentor teachers in order to improve their teaching (OTL14E) also shows some significant effects although the item has a negative beta coefficient. This may be because the prevalent view is that beliefs about science achievement in schools are undesirable and hence PSTs find it difficult to reconcile the feedback they receive with what their programmes enculture in them (Tillotson & Young, 2013). Planning that meets the PSTs' needs at certain stages of their preparation (OTL15A) accounts for the variance in beliefs about science achievement mean scores and the item has a negative beta coefficient as well. Sequencing courses such that content taught builds on previously taught content (OTL15B) and the assessment of low-level objectives (OTL6D) show some effects with regard to science achievement. Learners may be deemed knowledgeable when low-level objectives are assessed because of the low-level objectives' inability to discriminate between learners with different levels of physical science understanding. This may in turn enhance the desirable beliefs of the PSTs, because most learners, irrespective of their attributes, may show adequate achievement. Furthermore, OTL tertiary-level physical science (OTL2J) shows some effects with beliefs about science achievement.

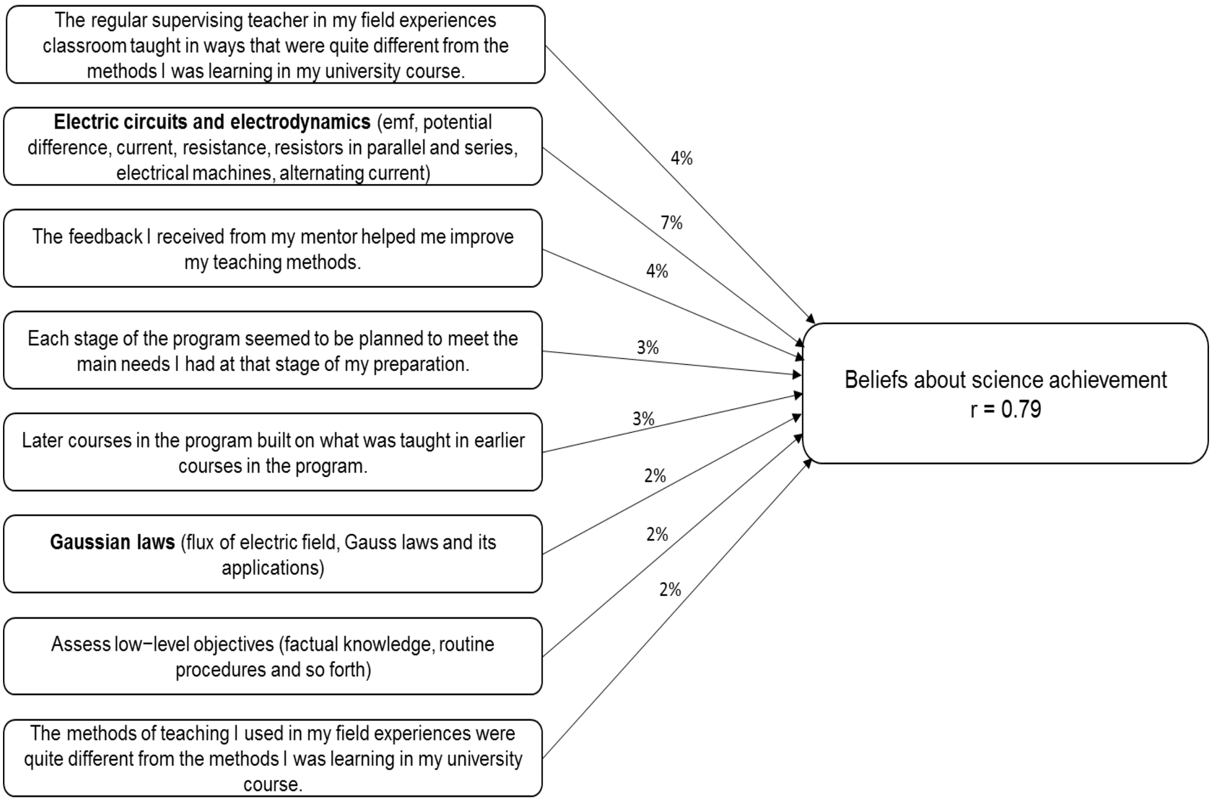


Figure 4.5: Regression analysis with beliefs about science achievement as the dependent variable

4.10.6 Combination of OTL scales that significantly affect PSTs' beliefs about preparedness for teaching physical science (BLF4)

Table 4.96 presents items that predict PSTs' beliefs about preparedness for teaching physical science. The prediction model contains seven predictors. It is reached in seven steps, with no variables removed. The model is statistically significant, $F(7,104) = 10.38$, $p = 0.000$, and accounts for approximately 73% of the variance of beliefs about preparedness for teaching physical science scores ($R^2 = 0.725$, Adjusted $R^2 = 0.706$). Beliefs about preparedness for teaching are primarily predicted by OTL15B ($\beta_1 = 0.313$, $p = 0.000$), OTL9D ($\beta_2 = 0.262$, $p = 0.001$), OTL6G ($\beta_3 = 0.221$, $p = 0.002$), OTL14C ($\beta_4 = 0.158$, $p = 0.019$), OTLP1K ($\beta_5 = -0.156$, $p = 0.005$), OTLC1N ($\beta_6 = 0.118$, $p = 0.030$), OTL9A ($\beta_7 = 0.126$, $p = 0.044$).

With

OTL15B	Later courses in the programme built on what was taught in earlier courses in the programme.
OTL9D	Observe teachers modelling new teaching practices
OTL6G	Develop instructional materials that build on learners' experiences, interests and abilities
OTL14C	My school-based mentor used criteria provided by my university when reviewing my lessons with me.
OTLP1K*	**Temperature, heat and laws of thermodynamics** (Celsius and Fahrenheit scales, laws of thermodynamics, thermal expansion, heat and work, entropy)
OTLC1N	**Acids and bases** (acid-base concepts, acid base strengths, self-ionization of water, pH)
OTL9A	Develop research projects to test teaching strategies for learners of diverse abilities

The regression equation with beliefs about preparedness for teaching physical science, as the dependent variable is as follows:

$$Y = \beta_0 + 0.313X_1 + 0.262X_2 + 0.221X_3 + 0.158X_4 - 0.156X_5 + 0.118X_6 + 0.126X_7$$

Table 4.96: Regression analysis – beliefs about preparedness for teaching physical science

Coefficients							
Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	sr^2
		B	Std. Error	Beta			
7	(Constant)	0.656	0.214		3.068	0.003	
	OTL15B	0.254	0.055	0.313	4.589	0.000	0.056
	OTL9D	0.211	0.056	0.262	3.766	0.000	0.038
	OTL6G	0.174	0.054	0.221	3.192	0.002	0.027
	OTL14C	0.132	0.055	0.158	2.381	0.019	0.015
	OTLP1K	-0.379	0.132	-0.156	-2.879	0.005	0.022
	OTLC1N	0.310	0.141	0.118	2.202	0.030	0.013
	OTL9A	0.102	0.050	0.126	2.044	0.044	0.011

a. Dependent Variable: BLF4. R^2 = 0.725, Adjusted R^2 = 0.706, *p <0.05
b. sr^2 is the square semi-partial correlation

Beliefs about preparedness for teaching are predicted by sequencing courses, such as that content taught builds on previously taught content (OTL15B) and observing other teachers modelling new teaching strategies (OTL9D) shows some effects as shown in Figure 4.6. Tillotson and Young (2013) also show that the sequencing of content and the opportunity to observe teachers have a positive impact on teacher preparedness to teach science. Ingvarson *et al* (2007) also found that modelling good teaching practices to PSTs is a significant predictor of their preparedness. Development of research projects to test teaching strategies for learners with diverse abilities (OTL9A) and the development of teaching materials that build on learners' experience, interests and abilities (OTL6G) are also predictors of the said independent variable. It makes sense that having the opportunity to experiment with various strategies will have a positive effect on the PSTs' beliefs. This will allow them to test the best strategies to use and to discover under what type of conditions are these strategies effective. The use of criteria provided by the university when reviewing PSTs' lessons (OTL14C) and the OTL tertiary-level physics and chemistry (OTLP1K and OTLC1N) show some effects with beliefs about preparedness for teaching. Koc (2012) reports that PSTs experience challenges with regard to the methods mentor teachers employ and they feel less prepared to teach as result. The use of similar criteria is imperative, as it will also improve the theory-practice link and it is hoped that this would lead to better-prepared teachers. OTL content knowledge shows some effects, although the PSTs in Palmer's (2008) study mentions that CK as presented in their courses offered very little in terms of preparing them to teach.

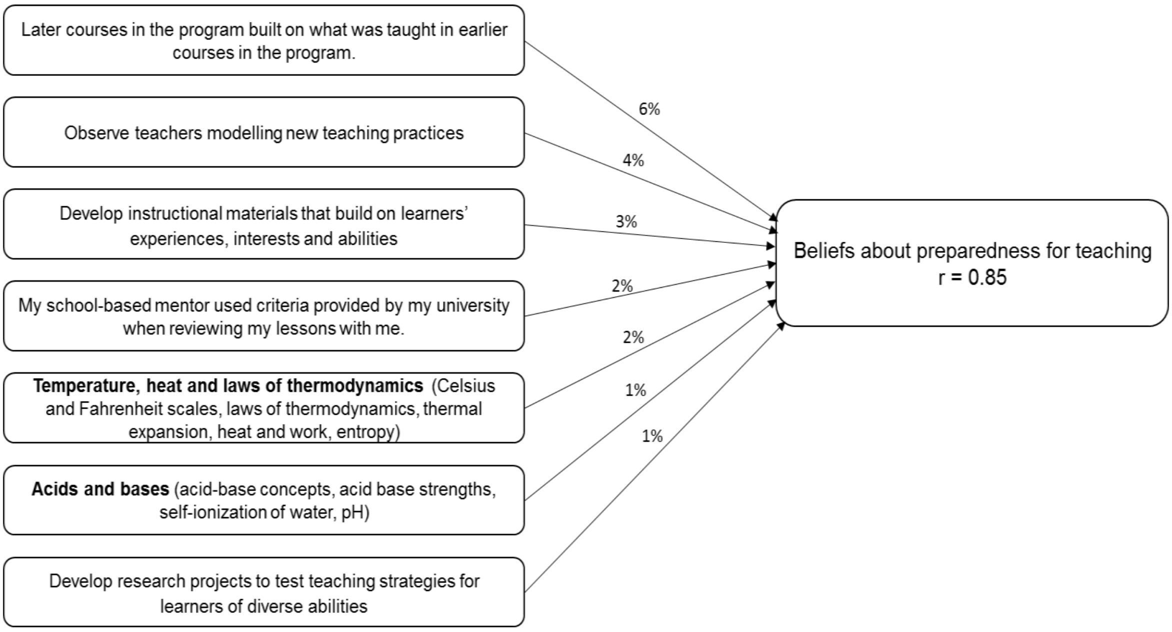


Figure 4.6: Regression analysis with beliefs about preparedness for teaching as the dependent variable

4.10.7 Combination of OTL scales that significantly affect PSTs' beliefs about programme effectiveness (BLF5)

Table 4.97 presents items that predict PSTs' beliefs about programme effectiveness. The prediction model contains seven predictors. It is reached in seven steps, with no variables removed. The model is statistically significant, $F(7,104) = 39.24$, $p = 0.000$, and accounts for approximately 73% of the variance of beliefs about programme effectiveness ($R^2 = 0.725$, Adjusted $R^2 = 0.707$). Beliefs about programme effectiveness are primarily predicted by OTL9D ($\beta_1 = 0.286$, $p = 0.000$), OTL15B ($\beta_2 = 0.199$, $p = 0.005$), OTL6J ($\beta_3 = 0.169$, $p = 0.020$), OTL9A (β_4 = 0. 189, p = 0.003), OTL14D (β_5 = 0.172, p = 0.012), OTL15C (β_6 = 0. 207, p = 0.007), OTL14E (β_7 = -0.145, p = 0.033).

With

OTL9D	Observe teachers modelling new teaching practices
OTL15B	Later courses in the programme built on what is taught in earlier courses in the programme
OTL6J	Integrate physical science ideas from across areas of science
OTL9A	Develop research projects to test teaching strategies for learners of diverse abilities
OTL14D	In my field experience, I had to demonstrate to my supervising teacher that I could teach according to the same criteria used in my university course
OTL15C	The programme is organised in a way that covered what I needed to learn to become an effective teacher
OTL14E*	The feedback I received from my mentor helped me to improve my teaching methods

The regression equation with beliefs about programme effectiveness as the dependent variable is as follows:

$$Y = \beta_0 + 0.286X_1 + 0.199X_2 + 0.169X_3 + 0.189X_4 + 0.172X_5 + 0.207X_6 - 0.145X_7$$

Table 4.97: Regression analysis – beliefs about programme effectiveness

Coefficients							
		Unstandardized Coefficients		Standardized Coefficients			
Model		B	Std. Error	Beta	t	Sig.	sr^2
7	(Constant)	0.991	0.254		3.899	0.000	
	OTL9D	0.325	0.084	0.286	3.860	0.000	0.039
	OTL15B	0.227	0.079	0.199	2.873	0.005	0.022
	OTL6J	0.193	0.081	0.169	2.368	0.020	0.015
	OTL9A	0.216	0.071	0.189	3.026	0.003	0.024
	OTL14D	0.188	0.074	0.172	2.560	0.012	0.017
	OTL15C	0.261	0.095	0.207	2.757	0.007	0.020
	OTL14E	-0.185	0.086	-0.145	-2.162	0.033	0.012
a. Dependent Variable: BLF5. R^2 = 0.725, Adjusted R^2 = 0.707, *p <0.05 b. sr^2 is the square semi-partial correlation							

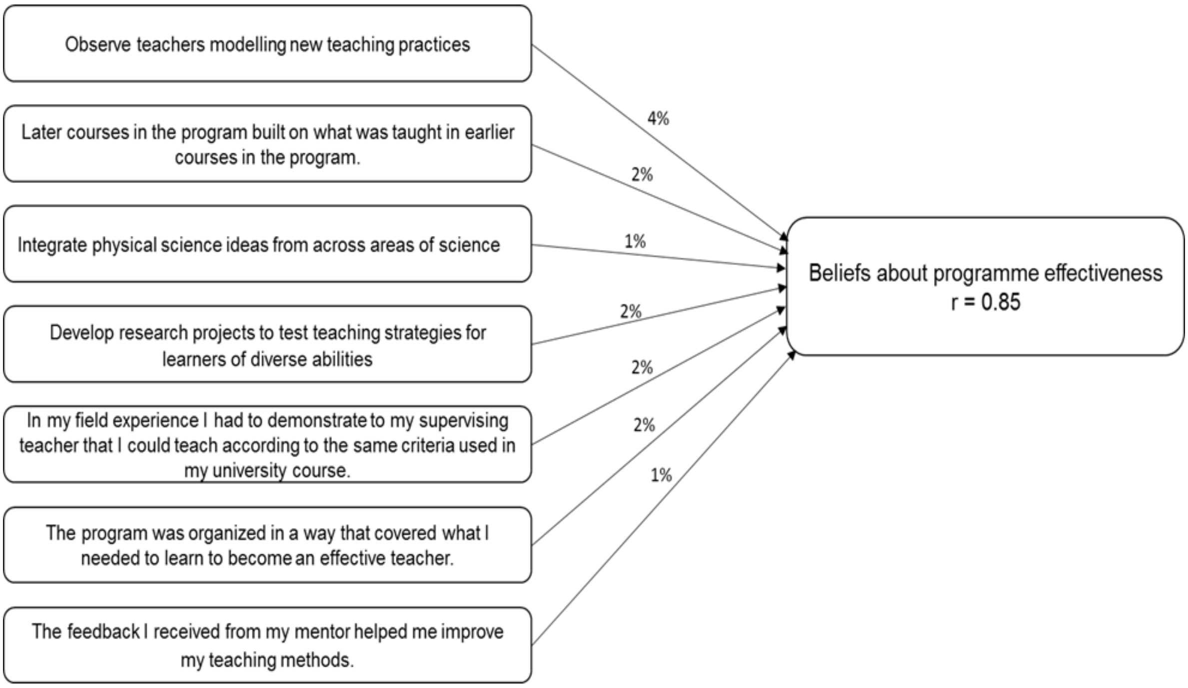


Figure 4.7: Regression analysis with beliefs about programme effectiveness as the dependent variable

Sequencing courses such that content taught builds on previously taught content (OTL15B) and observing other teachers modelling new teaching strategies (OTL9D) are predictors of beliefs about programme effectiveness (Figure 4.7). Numerous scholars have argued that the correct sequencing of content is a good indicator of an effective teacher education programme (Ingvarson *et al.*, 2007; Tillotson & Young, 2013). Feedback received about the PSTs' methods of teaching in order to improve their teaching (OTL14E), the development of research projects to test teaching strategies for learners with diverse abilities (OTL9A) and demonstrating that PSTS can teach according to the criteria provided by the university (OTL14D) shows some significant effects as well. The three predictors link together in this case. Affording PSTs opportunities to test effective strategies is good, but providing constructive feedback on the strategies is a good indicator of an effective programme. Additionally, the strategies enhance desirable beliefs if they are accompanied by actual demonstrations of how effective teaching occurs as guided by university criteria. The integration of ideas from across areas of science into physical science (OTL6J) and programme organisation in such a way that it assists PSTs to become effective teachers (OTL15C) also accounts for the variance observed in beliefs about programme effectiveness. The interesting observation is that this is the only model where OTL tertiary and school-level science (OTL1 and OTL2) items are not predictors of the dependent variable.

4.11 Conclusion

This chapter presented data for the three constructs that concerned the present study. Means from each university were presented and contrasted with one another. The chapter continued to present means, correlations and multiple linear-regression data for the entire sample of PSTs.

The data show most respondent's knowledge has gaps but they seem to hold desirable beliefs. The data also shows that universities of technology PSTs are exposed to significantly more OTL than traditional universities PSTs. The data further show that there are numerous types of associations between PSTs knowledge, beliefs and the OTL that they are afforded. The data indicates that there are significant OTL predictors for PSTs knowledge and beliefs and the OTL that are multiple predictors of aspects of PSTs competence will be discussed in chapter 5.

Chapter 5

Discussions of the findings and conclusion

5.1 Introduction

This chapter provides an overview of the study followed by a discussion of the key findings. The chapter also provides conclusions and implications of the study, including recommendations for further research and my final thoughts as the researcher. The present study used a quantitative approach to determine the relationships between the PSTs' knowledge, belief bundles and OTL, the first of its kind to do so in South Africa to date. The study is also the first of its kind in the country, to date, to measure teacher knowledge directly and to determine possible associations with various beliefs bundles and OTL that the PSTs are afforded in their teacher education programmes.

The design of the study allowed for comparisons of individual universities' data to assess differences or similarities in terms of the OTL they were afforded, as well as the subsequent effects on aspects of PSTs' competence. Although the comparison of the individual universities' data is not the main aim of the study, the data, nonetheless, provide insights into some of the issues discussed in the literature review chapter.

5.2 Overview of the study

The present study is anchored on the concept of competence and it allowed for the assessment of PSTs' knowledge and beliefs as aspects of teacher competence. The other aspect of competence, which consists of practical competence, could not be assessed because of time and the resources needed to measure such a variable using a moderately large sample reliably. The respondents were PSTs from two traditional universities and two universities of technology. This quantitative study used a questionnaire consisting of a knowledge, beliefs and OTL section to collect data. The data were subjected to statistical analysis using SPSS to assess the relationships between belief bundles, knowledge and OTL. The study used Pearson product moments and eventually linear regression was used to determine predictors for the dependent (knowledge and belief bundles) variables.

The study was guided by five questions, namely:

1. What is the level of knowledge of pre-service physical science teachers in some South African universities?

> This question aimed to assess the PSTs' knowledge of physical science content and pedagogical content knowledge. This section of the questionnaire was validated by having multiple authorities with the necessary knowledge provide suggestions on how to improve the phrasing of the items. The data from the pilot study were used to validate the items using Rasch analysis.

2. What are PSTs' beliefs about teaching and learning of physical science?

> This question aimed to assess the PSTs' belief bundles, which consisted of beliefs about the nature of science, learning science, science achievement, preparedness for teaching physical science and programme effectiveness. This section of the questionnaire was based on the TEDS-M instrument and was validated using Cronbach alphas and comparisons with other instruments in literature on science teacher beliefs.

3. What kinds of OTL are pre-service science teachers exposed to in some South African universities?

> This question aimed to assess the OTL that physical science preservice teachers are afforded in their respective teacher education programmes. The OTL that were assessed include OTL tertiary-level science, OTL school-level physical science, OTL physical science pedagogy, OTL through reflection, OTL through teaching practice and

OTL in a coherent programme. This section was also based on the on the TEDS-M instrument and it was validated using Cronbach alphas.

4. What are the relationships between PSTs' knowledge, beliefs and the OTL they are exposed to?

This question used data from the first three questions to determine the possible relationships between the three constructs. Correlation coefficients were calculated to illustrate possible associations between knowledge, beliefs and OTL.

5. Which OTL are significant predictors of multiple variables in the knowledge and beliefs constructs?

Linear regression analysis was used to determine the OTL that significantly predict the dependent variables. OTL that were predictors of multiple knowledge and belief bundles were established.

The fifth research question provides OTL that explain the variance observed in knowledge and belief bundles scores. The present study's aim is to determine the specific OTL that show predictive powers for multiple knowledge and belief bundles variables. These OTLs point to the main contribution of the present study, namely to determine the OTL that may provide the greatest purchase in terms of learning and preparing competent PSTs in teacher education programmes. The OTLs that are predictors of multiple dependent variables are summarised in the sections that follow.

The comparisons of the universities' scores were achieved by calculating mean scores for all the constructs, and comparing and contrasting the mean scores of the four universities. The scores were further subjected to ANOVA tests to determine if there were significant differences in the four universities' mean scores. Other tests such as the Levene's test and post-hoc tests (Games-Howell and Tukey's post-hoc tests) were performed to determine and identify the source of the observed significant variations in the universities' mean scores. The ANOVA tests were in fact a test of the following three hypotheses using variables in the constructs (knowledge, belief bundles and OTL):

- There are no statistically significant differences in the knowledge mean scores of the participating universities.
- There are no statistically significant differences in the belief bundles mean scores of the participating universities.
- There are no statistically significant differences in the OTL mean scores of the participating universities.

In most cases, the hypotheses were not supported with the exception of OTL school level physical science (OTL2: $p > 0.05$). The statistical equivalence of the universities OTL2 mean scores (see Table 4.31 & 4.41) may be because a significant portion of tertiary level physics and chemistry courses content contains topics that form part of school level physical science curriculum. The similarities may be the reason why most respondents indicated that they were afforded sufficient OTL school level physical science topics in their respective programmes and therefore this may account for the statistical equivalence in the universities mean scores.

5.3 Summary of comparisons of individual universities' data

This section provides a summary of the comparisons between knowledge, beliefs and OTL mean scores of the four participating universities.

5.3.1 Possible relationships between knowledge, beliefs and OTL scores of the four universities

Table 5.1 presents the three constructs' data in one table for comparative purposes. Initial analysis of the universities scores does not suggest any clear trends (directly or inversely

Table 5.1: Summary of means of the data for PSTs' knowledge, beliefs and opportunity to learn

University	CK	PCK	BLF 1	BLF 2	BLF 3	BLF 4	BLF 5	OTL 1	OTL 2	OTL 6	OTL 9	OTL 11	OTL 12	OTL 14	OTL 15
U1	46,6	56,9	8,3	33,3	62,5	33,3	37,5	0,75	0,95	2,44	2,63	2,60	2,75	2,13	2,77
U2	71,5	71,7	97,0	97,0	100,0	66,7	100,0	0,93	0,97	3,22	3,12	3,39	3,36	3,24	3,56
U3	41,9	53,1	31,3	56,3	43,8	75,0	93,8	0,93	0,92	3,28	3,50	3,47	3,50	3,25	3,72
U4	43,0	52,1	12,8	53,8	46,2	51,3	66,7	0,81	0,84	2,79	2,77	2,79	2,87	2,51	2,96
Ave	52,0	59,1	39,3	62,5	65,2	55,4	73,2	0,85	0,91	2,91	2,95	3,03	3,08	2,75	3,21

proportional) in the universities mean scores. For example, U3's OTL mean scores are on average, higher than any other universities' but the same universities' beliefs and knowledge mean scores are not necessarily the highest. Similarly, U1 has, on average, the lowest OTL mean scores, but the same universities' CK and PCK mean scores are higher than U4 mean scores, although U4's OTL mean scores are, on average, higher than U1's OTL mean scores.

The post-hoc tests reveal interesting results in terms of OTL mean scores. A Games-Howell post-hoc test illustrates that U2 mean scores are statistically equivalent to U3's scores ($p > 0.05$) in all the OTL variables except the OTL through reflection on practice (OTL9). The post-hoc test also indicates that U2 and U3 mean scores are not statistically equivalent to U1 and U4 mean scores. Although the universities cannot be categorised exclusively into two subsets for OTL through reflection on practice (OTL9) variable, U2 and U3, and U1 and U4 are nonetheless two of the subsets according to the Games-Howell post-hoc test.

Data therefore suggest that the universities may be divided into two groups, with U1 and U4 in one group, which is referred to as Group A; and U2 and U3 in another, which is referred to as Group B. Table 5.1 and the post-hoc tests indicate that the OTL data from U1 are almost comparable with data from U4. The same is true for data from U2 and U3. Furthermore, group B's OTL mean scores are statistically significantly higher than group A's mean scores.

The interesting observation about the findings is that group B represents universities of technology while group A represents traditional universities. This observation may partially be explained by the amount of time reserved for teaching practice in traditional universities and university of technology. For example, one of the traditional universities reserved 23 weeks spread approximately evenly over the PSTs four years of study for teaching practice (approximately 6 weeks per academic year). On the contrary, one of the universities of technology reserved significantly more time for teaching practice. The first three years were allocated approximately six weeks each of teaching practice time and additionally, they were expected to spend the first six months of their final year of training in schools. This allocation of teaching practice time provides support to the notion that university of technology do expose their PSTs to significantly more practical aspects of teaching than their traditional university counterparts. Furthermore, the same traditional university expected their PSTs to have second year physics and chemistry minimum while the university of technology required their PSTs to have third year physics and chemistry. This further help explain the finding that universities of technology expose their PSTs to more OTL than traditional universities do. This account is based on contrasting only two universities curricula and it does not account for all other OTL, therefore it may not be a true reflection of all traditional universities and universities of technology teacher education programmes in South Africa. However, the account provides some useful clues with regards to the observed significant differences in OTL offered.

Further analysis of Group A and B mean scores reveal that on average Group B report more desirable beliefs than Group A (see Table 5.1). Considering that Group B respondents also indicate that they are exposed to more OTL, data seems to suggest that an increase in OTL may result in an increase in PSTs desirable beliefs (proportional relationship). Only beliefs about science achievement (BLF 3) violate this trend. Data illustrate that CK and PCK mean scores also violate this observation, because there are no clear trends between the OTL construct mean scores and knowledge construct mean scores.

In summary, the data seem to suggest that there are trends between OTL variables and belief bundles, but no trends (directly or inversely proportional) could be ascertained between OTL and knowledge mean scores. This is not to suggest that there are no possible associations between OTL variables' scores and knowledge scores, but it is to point out that this type of analysis does not reveal the possible associations between the two constructs.

A closer look at Group B's belief bundles and knowledge mean scores reveal an interesting phenomenon. Despite reporting comparable OTL, there are differences in the beliefs and knowledge mean scores of respondents from U2 and U3. The interesting observation is that

U2 respondents report higher frequencies of desirable beliefs in all but beliefs about preparedness for teaching variable between the two universities. The post-hoc tests reveal that beliefs about nature of science, learning science and science achievement scores between the two universities are not statistically significantly equivalent (Table 4.17, 4.20 & 4.23 respectively). Furthermore, the same trend is observed in the knowledge construct. The post-hoc tests reveal that CK and PCK mean scores for the two universities are not statistically significantly equivalent (Table 4.6 & 4.9). This implies that PSTs beliefs may have an effect on their knowledge and the converse may also be true that PSTs' knowledge may have an effect on their beliefs, as suggested by Mansour (2008). It is therefore possible that the interaction of knowledge and beliefs accounts for the variance observed in both knowledge and belief bundles constructs, while OTL is kept constant. Literature provides some guidance on this issue. Lortie (2002) and Kutálková (2017) suggest that teachers' beliefs are shaped by their training and that beliefs act as a contextual filter that assists teachers in structuring their teaching experiences and, subsequently, to adapt their practices. In the same line of thinking, Kagan (1992) and Tondeur *et al* (2016) suggest that beliefs act as a filter through which new knowledge is screened. Veal (2004) also suggests that PSTs' beliefs act as a filter for the development of PCK. The present study's findings therefore seem to support the stance that beliefs act as filter for knowledge construction. The beliefs that serve as filters according to the findings are beliefs about the nature of science (BLF1), learning science (BLF2) and science achievement (BLF3).

On the contrary, a closer look at Group A's mean scores reveal that U1 and U4 mean scores are statistically equivalent for all three constructs indicating that the trends in Group A are not similar to trends in Group B. The findings therefore suggest that the observation that beliefs act as a filter for knowledge cannot be regarded as conclusive, but the findings suggest that the said link between knowledge and beliefs may exist under certain conditions. The condition in the present study's case may be considered to be higher OTL mean scores.

5.4 Summary of the key findings

This section discusses the OTL that show predictive powers for multiple knowledge and belief bundles variables. This strategy is used to identify the OTL that may form the basis of effective science teacher education programmes.

Table 5.2 presents the OTL that are predictors of multiple dependent variables. OTL tertiary-level physics and chemistry, and school-level physical science items are not included in this table. For the sake of simplicity, the items that are predictors of the mentioned OTL are replaced with OTL1 and OTL2 respectively. Only OTL that predicted more than one belief bundles and/or knowledge variables included in the table.

Table 5.2: OTL that predict multiple dependent variables (knowledge and beliefs)

Frequency	CK	PCK	BLF1	BLF2	BLF3	BLF4	BLF5
5	OTL1	OTL1	OTL1	OTL1		OTL1	
4	OTL14G		OTL14G	OTL14G	OTL14G		
4		OTL14H	OTL14H	OTL14H	OTL14H		
4	OTL15B				OTL15B	OTL15B	OTL15B
3		OTL2		OTL2	OTL2		
3	OTL6D	OTL6D			OTL6D		
2		OTL6J			OTL6J		
2						OTL9A	OTL9A
2						OTL9D	OTL9D
2					OTL14E		OTL14E
2				OTL15A	OTL15A		

5.4.1 OTL tertiary-level and school-level content (OTL1 & OTL2)

The findings show that OTL tertiary-level physics and chemistry, and OTL school-level physical science are significant predictors of multiple aspects of PSTs' competence. The data show that OTL tertiary-level physics and chemistry is a significant predictor of five of the variables and OTL school-level physical science is a significant predictor of three variables. The findings therefore support the notion that PSTs need to be exposed to tertiary-level physics and chemistry because of possible effect on their CK and PCK, and they need to be exposed to school-level physical science because of the possible effect on PSTs' PCK. This finding in a sense provides another perspective to the breadth-versus-depth debate regarding the content PSTs are exposed to (Schwartz *et al.*, 2009). While OTL tertiary-level physics and chemistry is a predictor of both CK and PCK, OTL school-level physical science is a predictor of PCK and not CK. This means that OTL school-level physical science also affects PSTs knowledge and it could possibly enhance PSTs' PCK.

OTL tertiary-level physics and chemistry is a predictor of three beliefs bundles and OTL school-level physical science is a predictor of two beliefs bundles. Ingvarson *et al* (2007) also determined that, similar to the present studies' findings, the OTL science content is a predictor of most of the PSTs' outcomes measures. The other finding from the present study is that both OTLs are not predictors of beliefs about programme effectiveness. This suggests that while it is important to expose PSTs to physical science-related content, this may not have positive associations with their beliefs about the effectiveness of their teacher education programmes.

The present study's findings suggest that in terms of PSTs' learning, OTL tertiary-level physics and chemistry provides greater purchase in terms of learning than OTL school-level physical science. In terms of breadth and depth of content debate, the findings suggest that depth is a better predictor of aspects of PSTs' competence. This finding is supported by Schwartz *et al*'s (2009) assertions that deep learning is better in terms of learning than breadth learning. While this is so, the finding suggests that it may be worthwhile to afford PSTs the OTL school-level physical science as well. This view is similar to Hirsch's (2001) statement that the breadth and depth polarisations will not result in students' optimal learning but diverse and balanced learning experiences may yield enhanced learning.

5.4.2 OTL physical science pedagogy (OTL6D & OTL6J)

Integration of ideas from other science disciplines in the teaching of physical science is a significant predictor of some aspects of PSTs' competence. Physical science, as with other science disciplines, draws on knowledge from various science fields. Teachers are therefore expected to have deep knowledge of physical science topics and, additionally, other science disciplines besides physical science. This is desirable because PSTs will be expected to integrate and link topics they teach in the classroom to major advances in science and technology (Palmer, 2008). This finding may point to the combinations of courses that PSTs are allowed to take in their training. There are some instances where PSTs are allowed to take physical science/physics and chemistry, as well as a language, for example. This finding suggests that this may not be desirable and designers of PSTs could rather advise future science teachers to take other science-related courses instead of taking a course that has no relevance to science in general.

Other aspects, including the assessment of low-level objectives predict multiple aspects of PSTs' competence. The predictive power of assessment of low-level objectives might stem from the fact that these are relatively straightforward objectives and tasks normally planned for such objectives are of low cognitive demand. PSTs' beliefs may be enhanced by engaging in this type of activity, simply because it offers little complexity and it is easy to do for learners. This finding is somewhat complex in nature. While data suggest that the assessment of low-level objectives may be beneficial to PSTs, this may not necessarily be the case for learners. Low-level objectives provide a good knowledge base, but the nature of physical science requires learners to engage in learning through higher levels of inquiry (Abd-El-Khalick, 2013). This means that the assessment of higher-level objectives is more desirable in terms of learner learning. The present study's data indicates that PSTs are afforded more opportunities to assess low-level objectives (M = 3.29, SD = 0.85) than high level objectives (M = 3.00, SD = 0.90). In line with this perception of the predictive power of low-level objectives, there may be a need to expose PSTs to more inquiry-based scenarios in teaching and learning. The probable place PSTs may have the opportunity to hone their skills in inquiry learning is through laboratory work at universities and, more importantly, in schools with learners. Part of the teaching practice should therefore be reserved for interactions of PSTs with learners in a laboratory setup or through service learning.

5.4.3 OTL through reflection (OTL9A and OTL9D)

OTL through projects on testing teaching strategies that accommodate diverse learner abilities, is a predictor of beliefs about teacher preparedness and programme effectiveness. The finding suggests that the more PSTs are engaged in the practice of reflection when they are involved in teaching projects, the more aspects of their competence may be enhanced. It is normal practice for PSTs to be exposed to new teaching strategies in their training, but whether they are allowed a space to test these strategies and to reflect on various teaching strategies in practice is an open question at this stage. The portfolios that PSTs are expected to compile after teaching practice do contain their reflections on the whole teaching experience but some PSTs may include the reflective journals as a matter of compliance. Micro teaching/lessons in this regard present a space where PSTs may be afforded an opportunity to engage in reflective practice but these are normally very few and the quality of the debriefing session may differ across institutions. All these points may account for the predictive power of reflecting on teaching strategies.

The findings also suggest that aspects of PSTs' competence are affected by observing experienced teachers model new teaching practices and engaging in reflection afterwards. PSTs usually report that they do not have ample opportunity to observe mentor teachers in practice and that they are normally left alone to handle classrooms (du Plessis, 2013; Grossman *et al*., 2008). Data from the present study indicates that the respondents are afforded the OTL reflect on lessons presented by experienced teachers (M = 3.07, SD = 0.97) but the fact that this OTL is a predictor indicates that the respondents scores vary considerably. The findings therefore suggest that it is imperative for in-service teachers or teacher educators to model new teaching strategies so that PSTs may have the opportunity to observe and reflect on their observations. There are interventions that are suited to help PSTs to engage in reflection and the interventions address the two OTLs that are discussed in this section. Lesson study is one such intervention and it will be discussed briefly at a later stage in this chapter.

5.4.4 OTL through teaching practice (OTL14E, OTL14G & OTL14H)

Issues with regard to the link between theory and practice come out strongly as well. The link between teaching methods used schools and methods PSTs learn in teacher education is a predictor of all dependent variables tested, with the exception of beliefs about programme effectiveness. The findings also support the fact that field experiences are an important part of teacher education a suggested by Roychoudhury and Rice (2013). Taylor's (2014) report indicates that PSTs in South African universities engage in teaching practice for anything between 10 and 35 weeks and the quality of experiences differ significantly. The differences suggested by Taylor may account for the variations observed in the PSTs mean scores. Indeed, the structure and nature of experiences may affect PSTs' beliefs and their notion of effective teaching (Tillotson & Young, 2013). Ingvarson *et al* (2007) found that PSTs were having difficulty in applying the knowledge they gained in their teacher education programmes. The authors attribute this situation to the fact that it is difficult for universities to provide teacher educators that reinforce what the PSTs learn and the fact that it is rare that mentor/supervising teachers receive extensive training on mentoring. There is comprehensive literature on this subject and the general trend is that there needs to be a third space where theory and practice can interact as suggested by Zeichner (2010). The third space will assist in bringing experienced teachers, teacher educators and PSTs together where knowledge and effective methods and strategies can be discussed, tried and tested (Ball & Forzani, 2009).

A peculiar case is where feedback received from mentor teachers by PSTs is a predictor of beliefs about science achievement (β = -0.251, p = 0.001) and programme effectiveness (β = -0.145, p = 0.033) but the beta coefficients are negative in both instances, indicating suppressive effects on the said beliefs. Considering that coherence between theory and practice is an important aspect as far as aspects of PSTs' competence are concerned, it is possible that the type of feedback they receive reinforces beliefs that are not consistent with what they are exposed to at their respective institutions (Grossman *et al.*, 2008; Hammerness, 2006). As a result, the more PSTs are exposed to the feedback that does not reflect the experiences they are exposed to in their teacher education programmes, the less desirable beliefs they will hold and this may disrupt their learning processes. Ingvarson *et al* (2007) argue that feedback is the mechanism through which coherence between theory and practice can be achieved. The authors further found that while PSTs valued feedback they received from mentor teachers, relationships between the feedback PSTs receive and the theory they were exposed to at universities was uncertain. The third space referred to earlier may assist in this instance as well in that it may afford teacher educators and mentor teachers a space to share knowledge from both sides of the fence.

5.4.5 OTL in a coherent programme (OTL15A & OTL15B)

Structural aspects of teacher education programmes are predictors of aspects of PSTs competence. Some studies have investigated the sequencing of content and similar to the present study's findings, it was found to be a strong predictor of PSTs' competence (Tillotson & Young, 2013; Ingvarson *et al.*, 2007). It is important that knowledge and courses be sequenced in a cumulative nature, because such aspects of teacher education affect aspects of PSTs' competence as suggested by Rusznyak (2015) and the findings from this study. In support of this notion, Shay (2013: 567) argues that curricular coherence depends on "what gets selected, how it is sequenced, paced and evaluated".

Planning that meets the needs of PSTs at specific points in their preparation is also a predictor of aspects of teacher education. Zeichner (2010) argues that there has to be a just-in-time kind of interventions to ensure that PSTs' needs are catered for at every stage of their preparation. It is therefore important for teacher educators to have an understanding of PSTs' needs at various stages of their preparation, as this will allow them to devise responsive interventions that affect aspects of PSTs competence.

In summary, the OTL discussed above are significant predictors of aspects of PSTs competence and their emphasis in the design or recontextualization of physical science teacher education may enhance the quality of the programmes, which may in turn enhance aspects of PSTs competence.

5.5 Key OTL for the design of teacher education programmes

Teacher education programmes offer PSTs a range of OTL and innovations in hopes that the PSTs will be sufficiently prepared to embark on a teaching career successfully. A reasonable assumption is that these OTL affect the competence of PSTs in various ways. The present study was in a way designed to test the effects and more importantly, the effectiveness of some of the more prevalent OTL offered by a large majority of teacher education programmes in South Africa.

Table 5.2 shows OTL that are predictors of more than one dependent variable. The table also shows that there are OTL that are predictors of four or more dependent variables. In terms of the main aim of this study, these represent OTL that may give the greatest purchase in terms of PSTs' learning. I will therefore expand and provide an account for the predictive power of the key OTL and how they influence the respective knowledge and belief bundles variables.

5.5.1 Key predictors for PSTs competence

Unsurprisingly, one of the predictors of four or more dependent variables is OTL tertiary-level physics and chemistry (OTL1). The OTL content is necessary for PSTs to develop into competent teachers. This is also substantiated by literature from professional development. One of the elements of effective professional development is that it should focus on content (Darling-Hammond & Richardson, 2009; Desimone, 2011; Guskey, 2003). The finding is intuitive in numerous ways and simply put, a teacher needs to be knowledgeable and an expert in the content that they will be teaching. The mastery of physical science content in this case not only enables the teacher to use higher order questions, appropriate analogies and argumentation in lessons, but it also has a profound effect on their beliefs including beliefs about effective teaching and learning of content. The OTL about the structure and processes of physical science will lead to teachers who value the same processes and who strive to instil the same values in their learners (Mansour, 2013). In the context of this study, the predictive power of OTL tertiary level science may be considered from three perspectives. Firstly, while PSTs are exposed to tertiary level physics and chemistry in their programmes, there are instances where they attend classes in physics and chemistry departments together with students who specialize in the subjects. On the contrary, there are some programmes where tertiary physics and chemistry are offered within the teacher education programmes. This may lead to differences in the OTL experienced by PSTs and therefore differences in the effects of the OTL on PSTs competence. Secondly and on the same note, there are some programmes where PSTs do receive tuition from specialist departments but their physics and chemistry modules are modified to meet the needs of prospective physical science teachers as in the case of Palmer (2008). The present study is not designed to test if the observed variation in knowledge and belief bundle mean scores are as a result of the said tertiary physics and chemistry offerings but since some of the participating universities fall in the categories of content offerings mentioned, this may account for the variations observed. Thirdly, part of the what possibly explains the variations in the universities mean scores lies in their interpretation of how to integrate the knowledge areas. For example, although MRTEQ prescribes that 50% credits should be allocated to content specific knowledge, some of the participating universities had less than what is prescribed. In fact, one of the universities participating in the present study had approximately 37% of the credits allocated to content specific knowledge. In the context of this finding, it is possible that this situation creates differences in the amount of content that PSTs are exposed to. This result brings to the fore the importance of affording PST quality, sufficient and effective OTL tertiary physics and chemistry because this may have a positive effect on aspects of PSTs competence.

OTL through sequencing of courses such that there are links between what is taught earlier and later in the programme (OTL15B) is a predictor of four or more dependent variables. Rusznyak (2015) argues that coherent experiences are a necessity in teacher education because this might lead programmes that prepare effective teachers better. It is crucial that modules not only link in the area of specialization (modules such as chemistry I, II, III) but there should also be links between most modules which are offered in teacher education. The combination of OTL which are offered in various modules should offer coherent experiences which assist PSTs to act accordingly in complex situations. In terms of policy (MRTEQ), the modules offered in teacher education must address the types of knowledge areas that are necessary for one to be an effective teacher. Even though MRTEQ prescribes five types of knowledge areas, namely disciplinary, pedagogical, practical, situational and foundational knowledge, the integration of these types of knowledge in practice is not automatic or easy to achieve (Hoban, 2005; Rusznyak, 2015). It is interesting to note that the beta coefficients for two of the predictors are negative indicating suppressive effects for the two dependent variables. This suggest that in some instances, the more there are links between what is taught earlier and later in the programme, the respondents CK ($\beta = -0.214$, $p = 0.004$), and beliefs about science achievement ($\beta = -0.264$, $p = 0.001$) are negatively affected. The collected data from the four universities does not offer any solid clues with regards to the plausible reasons why this seems to be the case. Be that as it may, the finding suggests that integration of courses offered in teacher education so that there are clear links between them and there is progression in terms of content taught is important in some instances and it seems to be a negative factor in other instances.

OTL that deal with similarities between methods and strategies that are used in schools and those the PSTs are exposed to are predictors of four or more dependent variables (OTL14H & OTL14G). Other large-scale studies such as the IMPPACT study have also found this to be the case (Tillotson & Young, 2013). Zeichner (2010) has shown that there were numerous investigations that were undertaken to try and understand the theory-practice dichotomy in teacher education. In general, the literature suggest that teacher effectiveness will be enhanced if what happens in schools is underpinned by the knowledge gained from the university. The mean score of respondents with regard to the links between theory and practice are on average lower (OTL14G: M = 2.40, SD = 1.06 & OTL14H: M = 2.24, SD = 1.13) than all other mean scores suggesting that there is little in terms of links between theory and practice and this may account for the variance observed in the knowledge and beliefs bundles mean scores. The other interesting observation is that there are moderately large and significant association between the theory-practice dichotomy and all of the knowledge and most belief bundles variables (see Table 4.81 & 4.89). The predictive power of the theory-practice dichotomy may also be explained or supported by the fact that OTL from feedback received from mentor teachers (OTL14E) is a predictor of more than one dependent variables. The argument here is that if the feedback does not match the knowledge that PSTs are exposed to, then it may have negative effects on aspects of their competence. This further supports the perceived associations between theory-practice dichotomy and aspects of PSTs competence. The finding suggests that uniformity between what happens in school and what

PSTs are exposed to in their teacher education is an important feature of teacher education programmes.

5.5.2 Macro-view of key OTL for the design of effective teacher education programmes

The OTL that are predictors of more than four knowledge and belief bundles' variables seem to suggest that *coherence* in both courses/modules offered and teaching practice is an aspect of teacher education that may provide the greatest purchase in terms of PSTs' learning.

I am inclined to agree with Grossman *et al*'s (2008) definition of coherence. The authors define coherence as the degree to which teaching and learning concepts are shared by stakeholders involved in teacher education with the aim of attaining certain goals, and the degree to which OTL are organised both logistically and conceptually towards the attainment of the goals mentioned. Furthermore, the authors define coherence as the degree to which programme structures such as teaching practice experiences and courses are designed to reflect, support and reinforce the shared ideas. Darling-Hammond's (2006: 306) vision of a coherent teacher education programme is a programme where the course work is

> carefully sequenced based upon a strong theory of learning to teach; courses are designed to intersect with each another, are aggregated into a well-understood landscape of learning, and are tightly interwoven with the advisement process and students' work in schools. Subject matter learning is brought together with content pedagogy through courses that treat them together; program sequences also create cross-course links. Faculty plan together and syllabi are shared across university divisions as well as within departments. Virtually all of the closely interrelated courses involve applications in classrooms where observations or student teaching occur. These classrooms, in turn, are selected because they model the kind of practice that is discussed in courses and advisement. In such intensely coherent programs, core ideas

are reiterated across courses and theoretical frameworks animating courses and assignments are consistent across the program.

The present study's main findings are a reflection of Grossman *et al* (2008) and Darling-Hammond's (2006) vision of a coherent teacher education programme. Although the scholars cited above and others such as Smeby and Heggen (2014) have investigated the concept of coherence as part of teacher education programmes, the present study's findings suggest that coherence could in fact, be a basis for designing quality, responsive and effective physical science teacher education programmes. The three OTL namely

- OTL tertiary level physics and chemistry (OTL1),
- OTL through sequencing of courses such that there are links between what is taught earlier and later in the programme (OTL15B) and
- OTL that deal with similarities between methods and strategies that are used in schools and those the PSTs are exposed to (OTL14G & OTL14H)

account for a significant portion of the variance observed in aspects of PSTs knowledge and belief bundles scores. Therefore, the accentuation of these three OTL in teacher may assist with designing responsive and effective physical science teacher education programmes. This may in turn assist universities in producing competent novice physical science teachers. It is therefore imperative for policymakers, programme designers and teacher educators to assess issues in and around aspects of coherence in their respective teacher education programmes critically according to the evidence provided in the present study.

5.6 Limitations of the study

The goal of the present study was to have respondents in every institution that offers initial teacher education in South Africa but it was not possible due to numerous reasons. One of the reasons was the #feesmustfall movements of 2016, which limited the number of universities I could access. The implication of which is that the findings cannot be readily generalised to the entire population of physical science PSTs in South Africa. The findings will therefore be suggestive instead of conclusive.

The achievement test also presented a limitation. Because of time constraints, only a limited number of items could be included in the test. After many deliberations, I decided to test only two of the five components of PCK, which meant that the number of CK items (18) was significantly more than the PCK items (6). I however, do realise that this view of PCK is limited, considering that Geddis (1993) and Rollnick and Mavhunga (2014) have shown that there are five components that affect teacher's transformation of content knowledge (see Rollnick & Mavhunga, 2014). The time I had to administer the questionnaire and the consideration that PSTs may have not had sufficient classroom exposure to develop the other three components (Loughran *et al.*, 2004) justified the decision to assess only two components of PCK. It was more important to measure two components reliably than to use one item for measuring each of the five components.

The achievement test consists of multiple-choice items and the findings may not reflect the true nature of the PSTs' knowledge. Although some sort of reasoning was included in most answers to items, it is not clear if the respondents truly understood the concepts. All that can be said is that the respondents were able to recognise the correct answer for an item.

As the achievement test represented a low-stakes test, PSTs may have not taken it seriously and this may have an effect on the findings. It is also possible that those who responded to the test had a genuine interest in physical science teaching and those with low interest may have chosen not to participate in the present study.

Memory effects may also play a role in the findings. It might be that the PSTs' account of variables such as teaching practice time and whether they studied a certain topic as part of their preparation through the years is not as accurate as it should be.

While the present study suggests that OTL tertiary-level physics and chemistry, OTL in a programme where there is proper sequencing and links between courses, and OTL in a programme where there are links between methodologies employed during teaching practice and the knowledge PSTs are exposed to at universities are important, the study in no way suggests these are the only important aspects of teacher education. Regression analysis provides good predictors of the dependent variables while other variables are kept constant and therefore it makes sense that other OTLs may form part of effective teacher education. What the present study's findings propose is that if all other OTLs are kept constant, an increase in the OTLs that are significant predictors of the dependent variables may have a positive impact on aspects of PSTs competence, which includes knowledge and beliefs.

5.7 Recommendations for practice and policy

Recommendations for policy and practice from the findings of the study are discussed in the section that follows.

5.7.1 Recommendations for practice

Although teacher education programmes in South Africa are designed by using the same framework (MRTEQ), there tends to be variations in the OTL that the PSTs are afforded, possibly because of each university's philosophy of good teacher preparation. At university level, teacher educators have responsibility to design and to afford PSTs experiences that may have a positive impact on aspects of their competence.

The findings suggest that there needs to be more monitoring and evaluation of teaching practice by teacher educators over and above the normal PSTs evaluation. There also needs to be more coherence in terms of what happens in schools and the expectations of the PSTs which are based on what they learned in their teacher education programmes. There is a need to inform mentor/supervising teachers of the expectations of the university and their role in ensuring that PSTs get the most in terms of learning through teaching practice experiences.

This is where teacher educators need to hold workshops and train mentor/supervising teachers about what they need to do and the kind of activities PSTs need to be engaged in when undertaking practicum. These workshops should not be a once off; the teacher educators could provide ongoing support to in-service teachers and schools (Darling-Hammond & Richardson, 2009; Desimone, 2011).

Coherence in terms of the courses and experiences needs attention as well. Shay (2013) argues that teacher education programmes should be based on what works and this idea encapsulates what is known as ‘reconceptualising principles’ in the current literature. Reconceptualising principles are the basis on which relative strengths, weaknesses and gaps in the curriculum are identified (Rusznyak, 2015). Teacher educators and curriculum designers should therefore, under the guidance of reconceptualising principles pay close attention to links and, subsequently, the manner in which courses are sequenced in physical science teacher education programmes.

Professional development interventions such as lesson study may be useful in providing a space for PSTs to test and sharpen their teaching methods and strategies under the guidance of experienced teachers and teacher educators. Lesson study is a school-based professional development approach where teachers collaborate in planning, implementing and reflecting on lessons designed to enhance learners’ comprehension of a topic (Lewis, 2009). The very nature of lesson study is to test strategies that may be effective in the teaching and learning of a subject such as physical science (Burghes & Robinson, 2010). The collaborative nature of the lesson study intervention may also be an asset insofar as bringing to life the theory that PSTs are exposed to at universities in a school setting using experimental lessons (Lawrence & Chong, 2010). Incidentally, lesson study also provides an ideal space for participants to reflect on their practice and this is desirable, given that the findings from the present study suggest that these kind of interventions may be an important part of teacher education programmes. The findings are therefore in support of the establishment and the inclusion of PSTs in school-based professional development interventions such as lesson study.

5.7.2 Recommendations for policy

Teacher education in South Africa, as with any other country, is regulated and this is evident because of the policies that are put in place to guide the manner in which the programmes are designed (e.g. MRTEQ).

In the US and Australia, Zeichner's (2010) notion of a third space was realised by the spread of professional development schools (PDS), which serve as a space where PSTs, teacher educators and in-service teachers can interact. PDS are regarded as the link between the classroom and teacher preparation, stated simply, the link between theory and practice (Buzza *et al*., 2010; Yuen, 2011). The establishment of a PDS may assist in addressing the theory-practice dichotomy that has plagued teacher education of late (Helms-Lorenz *et al.*, 2017).

While the MRTEQ policy document specifies the minimum amount of time PSTs are supposed to be engaged in teaching practice, there may be a need to have minimum standards that should be adhered to by all those offering teacher education. This point is emphasised by Jita (2016) where she asserts that there is a need to afford PSTs adequate experiences that are aimed at optimal learning within teaching practice. This can possibly be achieved by having mechanisms in place to monitor the OTL that are afforded to PSTs in practicum.

5.8 Future research

The present study has made strides in terms of associating PSTs' competence and certain aspects of teacher education operationalised as OTL. More of such studies should be designed to ascertain the notion that teacher preparation leads to competent teachers and to determine which aspects of teacher preparation, if emphasised, will likely lead to competent novice teachers including novice physical science teachers.

Future studies can endeavour to improve the measurement of the knowledge construct. The fact that knowledge was measured using actual tests provides methodological advantage, but the use of multiple-choice items is somewhat of a limitation. The number of items of the knowledge construct should be increased to cover more topics if possible, and the use of open-ended questions may provide a more accurate picture of PSTs' comprehension of science concepts.

Future studies should attempt to investigate a more representative sample of final year physical science PSTs as this will allow for generalisations to the entire population of PSTs and larger samples will be desirable in such an instance. Other aspects of PCK, including curricular knowledge and planning should be included to provide a more holistic picture of PSTs' PCK. Other PSTs attributes such as their matric (Grade 12) scores may play an important role towards their competence and hence future studies should endeavour to include such in their investigations.

It will be interesting to conduct investigations that include learner achievement data as well. Such studies may therefore test if and how PSTs' competence relates to learner achievement and they may provide information on the mediating effects of teacher beliefs, knowledge and skills on learner achievement.

Most PSTs now qualify to be teachers through the PGCE route and some teacher educators, principals, in-service teachers and other stakeholders are not in favour of this route of qualification according to anecdotal evidence. A comparative study between the BEd and PGCE candidates on the OTL they are exposed to may provide the education community with information on similarities and differences in their experiences of teacher education. Such studies may further ascertain if the rigorous content knowledge the PGCE candidates are exposed to enhances their competence in terms of knowledge, beliefs and skills.

An in-depth study is also needed where the concept of coherence is unpacked. Some researchers argue that although there is an increasing emphasis on the development of coherent education programmes, features that underpin such programmes are not properly understood in the literature (Grossman *et al*., 2008; Hammerness, 2006). There is therefore a need to investigate aspects of coherent teacher education programmes properly if the findings from the present study are to be realised.

5.9 Final thoughts

Teachers require effective and coherent experiences that focus on issues about teaching and learning in their preparation (Desimone, 2011). Teacher educators and teacher-education programme designers have a critical role of designing experiences that PSTs may draw on as they progress in their training (Rusznyak, 2015). OECD (2005) makes a bold claim that tweaking courses will not likely lead to any profound changes in the effectiveness of teacher education, but enhancing the OTL PSTs are exposed to in those courses may lead to more effective teacher education.

Teacher education programmes cannot address all the challenges that are faced by science teachers as they attempt to train future professionals in South Africa. Nevertheless, the current study has suggested some OTL that might provide the maximum purchase in terms of teacher learning in teacher education programmes. Indeed, recontextualising science teacher programmes is a mammoth task, but the best time to start is now if we as a country hope to improve the standard of science teacher preparation. This will hopefully address Adler *et al*'s (2009) long-standing claim that math and particularly science achievement in schools will not improve until we focus on *what works* in pre-service teacher education. Adler and her colleagues further emphasise that the driver for this recontextualisation should be ideas grounded in and informed by empirical research such as the ideas presented in the present study.

I believe the findings from this study have provided some empirical evidence that designers of learning experiences for PSTs may draw on for designing responsive and effective physical science teacher training, possibly for the entire country if the findings from the four universities are anything to go by. The present study presented aspects of teacher preparation that affect PSTs' knowledge and beliefs. The study further examined those OTL that predict multiple dependent variables in order to direct relevant authorities to aspects of preparation that show the greatest promise in terms of teacher education and PSTs' competence.

References

Abd-El-Khalick, F. 2013. Teaching with and about nature of science, and science teacher knowledge domains. *Science & Education*, **22**, 2087-2107.

Adler, J., Pournara, C., Taylor, D., Thorne, B. & Moletsane, G. 2009. Mathematics and science teacher education in South Africa: a review of research, policy and practice in times of change. *African Journal of Research in MST Education, Special Issue*. 28-46.

Adomßent, M. & Hoffmann, T. 2013. The concept of competencies in the context of education for sustainable development (ESD). *Education for Sustainable Development*, 1-21.

Aguirre, J. & Speer, N. M. 2000. Examining the relationship between beliefs and goals in teacher practice. *Journal of Mathematical Behaviour,* **18** (3), 327-356.

Akcay, H. & Yager, R. 2010. Accomplishing the visions for teacher education programs advocated in the national science education standards. *Journal of Science Teacher Education,* **21**, 643-664.

Akerson, V. L. 2005. How do elementary teachers compensate for incomplete science content knowledge? *Research in Science Education*, **35** (2-3), 245-268.

Akpo, S.E. 2012. *The impact of teacher-related variables on students' Junior Secondary Certificate (JSC) Mathematics results in Namibia*. Unpublished PhD thesis, Unisa: South Africa, Pretoria.

Aksan, Z. & Çelikler, D. 2015. Evaluation of the knowledge and misconceptions of science teacher candidates in turkey regarding the greenhouse effect through the use of drawings. *Journal of Education and Practice*, **6** (13), 112-120.

Anderson, L.M., Smith, D.C. & Peasley, K. 2000. Integrating learning and learner concerns: Prospective elementary science teachers' paths and progress. *Teaching and Teacher Education*, **16**, 547-574.

Angrist, J.D. & Guryan, J. 2008. Does teacher testing raise teacher quality? Evidence from state certification requirements. *Economics of Education Review*, **27** (5), 483-503.

Ary, D., Jacobs, L.C., Sorensen, C.K., & Walker, D.A. 2014. *Introduction to research in Education.* Wadsworth/Cengage Learning: Belmont, CA.

Atweh, B. & Abadi, A. 2012. Investigating teachers' pedagogical beliefs in Indonesia and Australia. *The Asia-Pacific Education Researcher,* **21** (2)*,* 325-335.

Avraamidou, L. & Zembal-Saul, C. 2005. Giving priority to evidence in science teaching: A first-year elementary teacher's specialized practices and knowledge. *Journal of Research in Science Teaching*, **42** (9), 965–986.

Aydeniz, M. & Kirbulut, Z.D. 2014. Exploring challenges of assessing pre-service science teachers' pedagogical content knowledge (PCK). Asia-Pacific Journal of Teacher Education, **42** (2), 147–166.

Aydin, S. & Boz, Y. 2012. Review of Studies Related to Pedagogical Content Knowledge in the Context of Science Teacher Education: Turkish Case. *Educational Sciences: Theory & Practice*, **12** (1), 497-505.

Aydın, S., Boz, N. & Boz, Y. 2010. Factors that are influential in pre-service chemistry teachers' choices of instructional strategies in the context of methods of separation of mixtures: A Case study. *The Asia-Pacific Education Researcher*, **19** (2), 251-270.

Aydın, S. & Çakıroğlu, J. 2010. Teachers' views related to the new science and technology curriculum: Ankara case. *Elementary Education Online*, **9** (1), 301-315.

Backhus, W.A. & Thompson, K.W. 2006. Addressing the nature of science in preservice science teacher preparation programs: science educator perceptions, *Journal of Science Teacher Education*, **17** (1), 65-81.

Ball, D.L. 2000. Bridging practices: Intertwining content and pedagogy in teaching and learning to teach. *Journal of Teacher Education,* **51** (3), 241-247.

Ball, D.L. & Forzani, F.M. 2010. What does it take to make a teacher? *The Phi Delta Kappan*, **92**, 8–12.

Ball, D.L., Thames, M.H. & Phelps, G. 2008. Content knowledge for teaching: what makes it special? *Journal of Teacher Education,* **59**, 389–407.

Bandura, A. 1993. Perceived self-efficacy in cognitive development and functioning. *Educational Psychologist,* **28**, 117–148.

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., & . . .Tsai, Y.M. 2010. Teachers' mathematical knowledge, cognitive activation in the classroom, and student progress. *American Educational Research Journal*, **47**, 133-180.

Beauchamp, C. 2015. Reflection in teacher education: issues emerging from a review of current literature. *Reflective Practice*, **16** (1), 123-141.

Bektas, O. 2015. Pre-service teachers pedagogical content knowledge in the physics, chemistry and biology topics. *European Journal of Physics Education,* **6** (2), 41-53.

Bell, R.L., Blair, L.M., Crawford, B.A. & Lederman, N.G. 2003. Just do it? Impact of a science apprenticeship program on high school students' understanding of the nature of science and scientific inquiry. *Journal of Research in Science Teaching*, **40**, 487–509.

Ben-Peretz, M. 2011. Teacher knowledge: What is it? How do we uncover it? What are its implications for schooling? *Teaching and Teacher Education*, **27**, 3-9.

Blomeke, S. & Kaiser, G. 2014. *Theoretical framework, study design and main results of TEDS-M*. In S. Blomeke et al. (eds). International Perspectives on Teacher Knowledge, Beliefs and Opportunities to Learn. Springer Science+Business Media: Dordrecht.

Blömeke, S., Kaiser, G., & Lehmann, R. 2010. *TEDS-M 2008—Professionelle Kompetenz und Lerngelegenheiten angehender Primarstufenlehrkräfte im internationalen Vergleich* [TEDS-M 2008—Professional competence and opportunities to learn of future primary teachers in an international comparison.] Münster, Germany: Waxmann.

Blomeke, S., Suhl, U., Kaiser, G. & Döhrmann, M. 2012. Family background, entry selectivity and opportunities to learn: What matters in primary teacher education? An international comparison of fifteen countries. *Teaching and Teacher Education*, **28**, 44-55.

Bolyard, J.J. & Moyer-Packenham, P.S. 2008. A review of the literature on mathematics and science teacher quality. *Peabody Journal of Education*, **83** (4), 509-535.

Bond, T.G. and Fox, C.M. 2007. *Applying the Rash model. Fundamental Measurement in Human Sciences*. Psychology Press: London.

Boyd, D., Grossman, P., Hammerness, K., Lankford, H., Loeb, S., McDonald, M., et al. 2008. Surveying the landscape of teacher education in New York City: Constrained variation and the challenge of innovation. *Educational Evaluation and Policy Analysis*, **30** (4), 319-343.

Boyd, D., Goldhaber, D., Lankford, H. & Wyckoff, J. 2007. The Effect of Certification and Preparation on Teacher Quality. *The Future of Children*, **17** (1), 45-68.

Boyd, D., Grossman, P., Lankford, H., Loeb, S. & Wyckoff, J. 2008. *Teacher preparation and student achievement (NBER Working Paper No. W14314)*. National Bureau of Economic Research: Cambridge, MA.

Boz, Y. & Uzuntiryaki, E. 2006. Turkish prospective chemistry teachers' beliefs about chemistry teaching. *International Journal of Science Education,* **28** (14), 1647–1667.

Bradley, J.D. & Mosimege, M.D. 1998. Misconceptions in acids and bases: A comparative study of student teachers with different chemistry backgrounds. *South African Journal of Chemistry*, **51** (3), 137–145.

Brouwer, C.N. 2010. *Determining long term effects of teacher education*. In P. Peterson, E. Baker, & B. McGaw (Eds.), International Encyclopaedia of Education, Vol. 7 (pp. 503-510). Elsevier: Amsterdam.

Bryan, L.A. 2003. The nestedness of beliefs: Examining a prospective elementary teacher's beliefs about science teaching and learning. *Journal of Research in Science Teaching,* **40***,* 835–868.

Bryan, L.A. 2012. *Research on science teacher beliefs*. In B. Fraser et al. (Eds.), Second International Handbook of Science Education (pp. 477–495). Springer International.

Bryan, L.A. & Atwater, M.M. 2002. Teacher beliefs and cultural models: A challenge for science teacher preparation programs. *Science Teacher Education*, **86**, 821– 839.

Burghes, D. & Robinson, D. 2010. *Lesson study: enhancing mathematics teaching and learning*. CBfT Education Trust, UK.

Buzza, D., Kotsopoulos, D., Mueller, J. & Johnston, M. 2010. Investigating a professional development school model of teacher education in Canada. *McGill Journal of Education*, **45** (1), 45-62.

Caena, F. & Margiotta, U. 2008. European Teacher Education: a fractal perspective tackling complexity. *European Educational Research Journal*, **9** (3), 317-331.

Canpolat, N., Pinarbasi, T. & Sozbilir, M. 2006. Prospective teachers' misconceptions of vaporization and vapor pressure. Journal of Chemical Education, **83** (8), 1237–1242.

Canrinus, E.T., Bergem, O.K., Klette, K. & Hammerness, K. 2017. Coherent teacher education programmes: taking a student perspective. *Journal of Curriculum Studies*, **49** (3), 313-333.

Capel, S. 2001. Secondary students' development as teachers over the a PGCE year. *Educational Research*, **43**, 247-261.

Carroll, J.B. 1989. The Carroll model: A 25-year retrospective and prospective view. *Educational Researcher*, **18** (1), 26-31.

Castle, S., Fox, R. K. & Souder, K. O. 2006. Do professional development schools (PDSs) make a difference: A comparative study of PDS and non-PDS teacher candidates. *Journal of Teacher Education,* **57***,* 65-80.

Cetin, P.S., Dogan, N. & Kutluca A.Y. 2014. The Quality of Pre-service Science Teachers' Argumentation: Influence of Content Knowledge. *Journal of Science Teacher Education*, **25**, 309–331.

Center for Development and Enterprise (CDE), 2013. *South Africa's Education Crisis 1994-2011*. Report by N. Spaull commissioned by CDE, Johannesburg.

Check, J. & Schutt R.K. 2012. *Research methods in education.* Washington DC: Sage Publications.

Cheng, M.M.H., Chan, K., Tang, S.Y.F. & Cheng, A.Y.N. 2009. Pre-service teacher education students' epistemological beliefs and their conceptions of teaching. *Teaching and Teacher Education*, **25**, 319–327.

Cochran-Smith, M. & Zeichner, K.M. 2005. *Studying Teacher Education: The Report of the AERA Panel on Research and Teacher Education (pp. 816).* Mahwah, NJ.

Cofre´, H., Gonza´lez-Weil, C., Vergara, C., Santiba´n˜ez, D., Ahumada, G., Furman, M., Podesta, M.E., Camacho, J., Gallego, R. & Pe´rez, R. 2015. Science Teacher Education in

South America: The Case of Argentina, Colombia and Chile. *Journal of Science Teacher Education*, **26**, 45–63.

Cohen, L., Manion, L. & Morrison, K. 2013. *Research methods in education*. Routledge: New York.

Collin, S., Karsenti, T. & Komis, V. 2013. Reflective practice in initial teacher training: Critiques and perspectives. *Reflective Practice: International and Multidisciplinary Perspectives*, **14**, 104–117.

Constantine, J., Player, D., Silva, T., Hallgren, K., Grider, M., Deke, J., & Warner, E. 2009. *An evaluation of teachers trained through different routes to certification (NCEE 2009-4043)*. IES: Washington, DC.

Consuegra, E., Engels, N. & Struyven, K. 2014. Beginning teachers' experience of the workplace learning environment in alternative teacher certification programmes: A mixed methods approach. *Teaching and Teacher Education*, **42**, 79–88.

Cooper, H., Robinson, J. C., & Patall, E. A. 2006. Does homework improve academic achievement? A Synthesis of research, *Review of Educational Research,* **76** (1), 1987-2003.

Council on Higher Education, 2010. *Universities of Technology – Deepening the Debate*. Kagisano No. 7, Jacana media: Pretoria.

Crawford, B.A. 2007. Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching,* **44**, 613–642.

Cresswell, J.W. 2014. *Research design: Qualitative, quantitative and mixed methods approaches*. Sage Publications: Washington, DC.

Daehler, K.R. & Shinohara, M. 2001. A complete circuit is a complete circle: exploring the potential of case materials and methods to develop teachers' content knowledge and pedagogical content knowledge of science. *Research in Science Education*, **31,** 267–288.

Darling-Hammond, L. & Bransford, J. 2005. *Preparing teachers for a changing world. Report of the Committee on Teacher Education of the National Academy of Education*. Jossey-Bass: San Francisco.

Darling-Hammond, L. 2006. Constructing 21st-century teacher education. *Journal of Teacher Education*, **57** (3), 300-314.

Darling-Hammond, L. & Richardson, N. 2009. Research review / Teacher learning: what matters? *How Teacher's Learn*, **66** (5), 46-53.

Darling-Hammond, L., Wei, R.C., Andree, A., Richardson, N. & Orphanos, O. 2009. *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. National Staff Development Council, Stanford University. Stanford.

Davis, E.A., Petish, D. & Smithey, J. 2006. Challenges new science teachers face. *Review of Educational Research*, **76** (4), 607–652.

de Jong, O. 2009. *Exploring and changing teachers' pedagogical content knowledge: An overview*. In: de Jong O, Halim L (eds). Teachers' professional knowledge in science and mathematics education: views from Malaysia and abroad (pp 1–25). Faculty of Education, The National University of Malaysia, Malaysia.

de Jong, O., Van Driel, J. & Verloop, N. 2005. Preservice teachers' pedagogical content knowledge of using particle models in teaching chemistry. *Journal of Research in Science Teaching*, **42**, 947-964.

Deluca, D., Gallivan, M.J. & Kock, N. 2008. Furthering information systems action research: a post-positivist synthesis of four dialectics. *Journal of the Association for Information Systems*, **9** (2). 48-72.

Desimone, L.M. 2009. Improving impact studies of teachers' professional development: toward better conceptualizations and measures. *Educational Researcher*, **38** (3), 181-199.

du Plessis, E. 2013. Mentorship challenges in the teaching practice of distance learning students. The Independent Journal of Teaching and Learning, **8**, 1 – 16.

Duschl, R.A., Schweingruber, H.A., & Shouse, A.W. 2007. *Taking science to school: Learning and teaching science in grades K-8*. National Academies Press: Washington, DC.

Erbe, B. 2000. *Correlates of student achievement in Chicago elementary schools*. Paper presented at the 2000 annual AERA meeting. American Educational Research Association; New Orleans, LA.

Etscheidt, S., Curran, C.M. & Sawyer, C.M. 2012. Promoting reflection in teacher preparation programs: a multilevel model. *Teacher Education and Special Education*, **35** (1), 7–26.

European Commission. 2013. *Supporting teacher competence development for better learning outcomes,* Strasbourg.

Evagorou, M., Dillon, J., Viiri, J. & Albe, V. 2015. Pre-service Science Teacher Preparation in Europe: Comparing Pre-service Teacher Preparation Programs in England, France, Finland and Cyprus. *Journal of Science Teacher* Education, **26**, 99–115.

Feiman-Nemser, S. 2008. *Teacher Learning. How do Teachers learn to teach?* In Cochran-Smith, M, Feiman-Nemser, S., McIntyre, D. (Eds.). Handbook of research on Teacher Education. Enduring Questions in Changing Contexts. Routledge/ Taylor & Francis: New York/Abingdon.

Floden, R.E. 2002. *The measurement of opportunity to learn*. In A.C. Porter & A. Gamoraxt (Eds.). Methodological advances in cross-national surveys' of educational achievement (pp. 231-266). National Academy Press: Washington, DC.

Fraser W.J., Killen, R. & Nieman, M.M. 2005a. Issues in competence and pre-service teacher education. Part 2. The assessment of teaching practice. *South African Journal of Higher Education*, **19** (2), 246±259.

Fraser W.J., Killen, R. & Nieman, M.M. 2005b. Issues in competence and pre-service teacher education. Part 1. Can outcomes-based programmes produce competent teachers? *South African Journal of Higher Education*, **19** (2), 229±245.

Friedrichsen, P.J., Abell, S.K., Pareja, E.M., Brown, P.L., Lankford, D.M., & Volkmann, M.J. 2009. Does teaching experience matter? Examining biology teachers’ prior knowledge for teaching in an alternative certification program. *Journal of Research in Science Teaching*, **46**, 357-383.

Garson G.D. 2015. *Missing data analysis and data imputation*. Statistical associates publishing, University of North Carolina.

Geddis, A.N. 1993. Transforming subject-matter knowledge: the role of pedagogical content knowledge in learning to reflect on teaching. *International Journal of Science Education*, **15** (6), 673-683.

Geddis, A.N., Onslow, B., Beynon, C. & Oesch, J. 1993. Transforming content knowledge: Learning to teach about isotopes. *Science Education*, **77**, 575–591.

Geijsel, F., Sleegers, P., Stoel, R. & Krüger, M. 2009. The Effect of Teacher Psychological, School Organizational and Leadership Factors on Teachers’ Professional Learning in Dutch Schools. *The Elementary School Journal*, **109** (4), 406-427.

Georgiou, S. & Tourva, A. 2007. Parental attributions and parental involvement. *Social Psychology of Education*, **10** (4), 473-482.

Goe, L. 2007*. The link between teacher quality and student outcomes: A research synthesis*. National Comprehensive Center for Teacher Quality: Washington, D.C.

Goe, L., Bell, C. & Little, O. 2008. *Approaches to evaluating teacher effectiveness: A research synthesis*. National Comprehensive Center for Teacher Quality: Washington, D.C.

Goldhaber, D.D., & Liddle, S. 2011. *The gateway to the profession: Assessing teacher preparation programs based on student achievement*. Center for Education Data and Research: Bothell, WA.

Gonzalez, J. & Wagenaar, R. 2005. *Tuning Educational Structures in Europe II. Universities' contribution to the Bologna Process*. (Eds.) University of Deusto & University of Groningen. http://tuning.unideusto.org/tuningeu/

Govender, N. 2015. Developing pre-service teachers' subject matter knowledge of electromagnetism by integrating concept maps and collaborative learning. *African Journal of Research in Mathematics, Science and Technology Education*, **19** (3), 306-318.

Green, S.B. 1991. How many subjects does it take to do a regression analysis? *Multivariate Behavioral Research,* **26**, 499-510.

Greenwood, A.M. 2003. Factors influencing the development of career-change teachers' science teaching orientation. *Journal of Science Teacher Education,* **14** (3), 217-234.

Groff, J. & Mouza, C. 2008. A framework for addressing challenges to classroom technology use. *AACE Journal*, **16** (1), 21–46.

Grossman, P. 2011. Framework for teaching practice: A brief history of an idea. *Teachers College Record*, **113** (12), 2836–2843.

Grossman, P., Hammerness, K.M., McDonald, M. & Ronfeldt, M. 2008. Constructing coherence structural predictors of perceptions of coherence in NYC teacher education programs. *Journal of Teacher Education*, **59** (4), 273-287.

Guskey, T.R. 2003. Analyzing lists of the characteristics of effective professional development to promote visionary leadership. *NASSP Bulletin*, **87**, 4-20.

Guskey, T.R. & Yoon, K.S. 2009. What works in professional development? *Phi Delta Kappan*, **90** (7), 495-500.

Hagger, H. & McIntyre, D. 2006. *Learning teaching from teachers. Realizing the potential of school-based teacher education*. Open University Press: Maidenhead.

Hajer, M. & Norén, E. 2017. Teachers' knowledge about language in mathematics professional development courses: from an intended curriculum to a curriculum in action. *Eurasia Journal of Mathematics, Science & The Future of Children*, **17** (1), 45-68.

Hammerness, K. 2006. From coherence in theory to coherence in practice. *Teachers College Record*, **108** (7), 1241-1265.

Hancock, E.S. & Gallard, A.J. 2004. Preservice science teachers' beliefs about teaching and learning: the influence of K-12 field experiences. *Journal of Science Teacher Education*, **15** (4), 281–291.

Hay-McBer, 2000. *Research into teacher effectiveness: A model of teacher effectiveness*. Research report No. 216. The Crown Copyright Unit: Norwich.

Heafner, T.L. & Fitchett, P.G. 2015. An opportunity to learn US history: What NAEP data suggest regarding the opportunity gap. *The High School Journal*, **98** (3), 226-249.

Helms-Lorenz, M., van de Grift, W., Canrinus, E., Maulana, R. & van Veen K. 2018. Evaluation of the behavioral and affective outcomes of novice teachers working in professional development schools versus non-professional development schools. *Studies in Educational Evaluation* **56**, 8-20.

Henry, J.J., Tryjankowski, A.M., Dicamillo, L. & Bailey, N. 2010. How professional development schools can help to create friendly environments for teachers to integrate theory, research, and practice. *Childhood Education*, **86** (5), 327-331.

Henze, I., van Driel, J.H. & Verloop, N. 2008. Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe. *International Journal of Science Education*, **30** (10), 1321–1342.

Hinkle, D.E., Wiersma, W. & Jurs, S.G. 2003. *Applied statistics for the behavioral sciences* (5th ed.). Houghton Mifflin: Boston, MA.

Hirsch, E.D. 2001. Seeking breadth and depth in the curriculum. *Educational Leadership*, **59** (2), 22-25.

Hoban, G.F. 2005. Developing a multi-linked conceptual framework for teacher education design. In Hoban, G.F. (Eds.), The missing links in teacher education design, Springer.

Hollins, E.R., & Torres-Guzman, M. 2005. *Research on preparing teachers for diverse populations*. In M. Cochran-Smith & K.M. Zeichner (Eds.), Studying teacher education: The report of the AERA Panel on Research and Teacher Education. Lawrence Erlbaum: Mahwah, NJ.

Hollins, E.R. 2011. Teacher preparation for quality teaching. *Journal of Teacher Education*, **62** (4), 395-407.

Howie, S.J., Long, C., Sherman, V. & Venter, E. 2008. *The role of IRT in selected examination systems*. An Umalusi Research Report: Pretoria.

Human Science Research Council (HSRC), 2011. *Highlights from TIMSS 2011.* HSRC: *South Africa*, Pretoria.

Ingersoll, R.M. 1999. The problem of underqualified teachers in American secondary schools. *Educational Research,* **28**, 26-37.

Ingvarson, L., Beavis, A. & Kleinhenz, E. 2007. Factors affecting the impact of teacher education programmes on teacher preparedness: implications for accreditation policy. *European Journal of Teacher Education*, **30** (4), 351-381.

Jita, T. 2016. Pre-service teachers' competence to teach science through information and communication technologies in South Africa. *Perspectives in Education*, **34** (3), 15-26.

Johnson, B. & Christen, L. 2012. *Educational research: Quantitative, quantitative and mixed approaches*. Sage Publication: Thousand Oaks.

Jüttner, M., Boone, W., Park, S. & Neuhaus, B.J. 2013. Development and use of a test instrument to measure biology teachers' content knowledge (CK) and pedagogical content knowledge (PCK). *Educational Assessment Evaluation Account*, **25**, 45-67.

Kagan, D.M. 1992. Professional growth among preservice and beginning teachers. *Review of Educational Research*, **62** (2), 129-169.

Käpylä, M., Heikkinen, J. & Asunta, T. 2009. Influence of Content Knowledge on Pedagogical Content Knowledge: The case of teaching photosynthesis and plant growth. *International Journal of Science Education*, **31** (10), 1395-1415.

Katane, & Selvi, K. 2006. Teacher competence and further education as priorities for sustainable development of rural school in Latvia. *Journal of Teacher Education and Training*, **6**, 41-59.

Kazempour, M. 2014. I can't teach science! A case study of an elementary pre-service teacher's intersection of science experiences, beliefs, attitude, and self-efficacy. *International Journal of Environmental and Science,* **9**, 77-96.

Kazempour, M. & Sadler, T.D. 2015. Pre-service teachers' science beliefs, attitudes, and self-efficacy: a multi-case study. *Teaching Education*, **26** (3), 247-271.

Kennedy, M. 1999. *The role of pre-service teacher education*. In Darling-Hammond, L. & Sykes, G. (Eds.). Teaching as the learning profession: handbook of teaching and policy. Jossey-Bass: San Francisco.

Keys, C.W. & Bryan, L.A. 2001. Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching,* **38** (6), 631-645.

Kind, V. 2014. A degree is not enough: A quantitative study of aspects of pre-service science teachers' chemistry content knowledge. *International Journal of Science Education*, **36**, 1313-1345.

Klieme, E., Hartig, J. & Rauch, D. 2008. *The concept of competence in educational Contexts*. In Hartig et al. (Eds). Assessment of Competencies in Educational Contexts. Hogrefe & Huber Publishers.

Koc, I. 2012. Preservice science teachers reflect on their practicum experiences. *Educational Studies*, **38** (1), 31-38.

Konig, J., Blomeke, S., Paine, L., Schmidt, B. & Hsieh, F.-J. 2011. General pedagogical knowledge of future middle school teachers. On the complex ecology of teacher education in the United States, Germany, and Taiwan. *Journal of Teacher Education*, **62**, 188-201.

Korthagen, F.A. J. 2004. In search of the essence of a good teacher: towards a more holistic approach in teacher education. *Teaching and Teacher Education*, **20**, 77-97.

Koster, B. & Dengerink, J.J. 2008. Professional standards for teacher educators: how to deal with complexity, ownership and function. Experiences from the Netherlands. *European Journal of Teacher Education*, **31** (2), 135-149.

Kratz, J. & Schaal. S. 2015. Measuring PCK – discussing the assessment of pck-related achievement in science teacher training. *Procedia - Social and Behavioral Sciences*, **19** (1), 1552-1559.

Kurz, A., Talapatra, D. & Roach, A.T. 2012. Meeting the curricular challenges of inclusive assessment: the role of alignment, opportunity to learn, and student engagement. *International Journal of Disability, Development and Education*, **59** (1), 37-52.

Kutálková, K. 2017. Beliefs of student of teaching: A case study. *Procedia - Social and Behavioral Sciences*, **237**, 1160-1165.

Lawrence, C.A. & Chong, W.H. 2010. Teacher collaborative learning through the lesson study: identifying pathways for instructional success in a Singapore high school. *Asia Pacific Educ. Rev*, **11**, 565-572.

Lewis, C.C. 2009. What is the nature of knowledge development in lesson study? *Educational Action Research*, **17** (1), 95-110.

Linacre, J. 2012. *Winsteps (Version 4.0.0.0 [Computer Software])*. Retrieved May 2016, from http://www.winsteps.com/

Litman, C., Marple, S., Greenleaf, C., Charney-Sirott, I., Bolz, M.J., Richardson, L.K., Hall, A.H., George, M. & Goldman, S.R. 2017. Text-based argumentation with multiple sources: A descriptive study of opportunity to learn in secondary English language arts, history, and science. *Journal of the Learning Sciences*, **26**, 1.

Little, R.J.A. & Rubin, D.B. 1987. *Statistical Analysis with Missing Data*. John Wiley & Sons: Brisbane.

Liu, E., Liu, C. & Wang, J. 2015. Pre-service Science Teacher Preparation in China: Challenges and Promises. *Journal of Science Teacher Education*, **26**, 29-44.

Long, D.A. 2014. Cross-national educational inequalities and opportunities to learn: conflicting views of instructional time. *Educational Policy*, **28** (3), 351-392.

Lortie, D.C. 2002. *School teacher: A sociological study.* University of Chicago Press, Chicago.

Loughran, J.J., Berry, A., Mulhall, P. & Woolnough, J. 2006. *Understanding and valuing the development of pedagogical knowledge in science teacher education*. In I. Eilks & B. Ralle (Eds.), Towards research-based science teacher education (pp. 65–76). Shaker Verlag: Aachen, Germany.

Loughran, J.J., Gunstone, R.F., Berry, A., Milroy, P. & Mulhall, P. 2000. *Science cases in action: Developing an understanding of science teachers' pedagogical content knowledge*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA, USA.

Loughran, J., Mulhall, P. & Berry, A. 2004. In search of pedagogical content knowledge in science: developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching*, **41** (4), 370–391.

Luft, J. 2009. Beginning secondary science teachers in different induction programs: The first year of teaching. *International Journal of Science Education*, **31** (17), 2355–2384.

Luft, J.A., Roehrig, G.H., & Patterson, N.C. 2003. Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practices, beliefs, and experiences. *Journal of Research in Science Teaching*, **40** (1), 77-97.

Macugay, E.B & Bernardo, A.B.I. 2013. Science coursework and pedagogical beliefs of science teachers: The case of science teachers in the Philippines. *Science Education International*, **24** (1), 63-77.

Magno, C. 2011. Exploring the relationship between epistemological beliefs and self-determination. *The International Journal of Research and Review,* **7** (1), 1-23.

Mahlomaholo, S., Letsie, L., Tlali, M., Letloenyane, M., Mosia, M., Janqueira, K., du Toit, S., Papashane, M., Chele, T. & Tshabalala, S. 2014. *Teaching and Learning Deficiencies in Physical Science, Mathematics and English in the North-West Dinaledi Schools: A Strategy for Improvement.* University of the Free State: Bloemfontein.

Mälkki, K., & Lindblom-Ylänne, S. 2012. From reflection to action? Barriers and bridges between higher education teachers' thoughts and actions. *Studies in Higher Education*, **37**, 33–50.

Mansour, N. 2008. The experiences and personal religious beliefs of Egyptian science teachers as a framework for understanding the shaping and reshaping of their beliefs and practices about Science-Technology-Society (STS). *International Journal of Science Education*, **30** (12), 1605-1634.

Mansour, N. 2009. Science teachers' beliefs and practices: issues, implications and research agenda. *International Journal of Environmental & Science Education*, **4** (1), 25-48.

Mansour, N. 2013. Consistencies and inconsistencies between science teachers' beliefs and practices. *International Journal of Science Education*, **35** (7), 1230-1275.

Mavhunga, E. & Rollnick, M. 2013. Improving PCK of Chemical Equilibrium in Pre-service Teachers. *African Journal of Research in Mathematics, Science and Technology Education*, **17** (1-2), 113-125.

McConnell, T.J., Parker, J.M. & Eberhardt, J. 2013. Assessing teachers' science content knowledge: a strategy for assessing depth of understanding. *Journal of Science Teacher Education*, **24**, 717-743.

McMillan, J.H. & Schumacher, S. 2014. *Research in education: Evidence based enquiry.* Pearson Education Incorporated: New Jersey.

Mo, Y., Singh, K. & Chang, M. 2013. Opportunity to learn and student engagement: a HLM study on eighth grade science achievement. *Education Research and Policy Practice*, **12**, 3-19.

Monk, D.H. 1994. Subject area preparation of secondary mathematics and science teachers and student achievement*. Economics of Education Review,* **13** (2), 125-145.

Moon, B. 2007. *Research analysis: Attracting, developing and retaining effective teachers: A global overview of current policies and practices*: UNESCO.

Moss, P., Pullin, D., Gee, J.P., Haertel, E. & Young, L.J. 2008. *Assessment, equity, and opportunity to learn*. Cambridge University Press: London.

Nakiboğlu, C., Karakoc, O. & De Jong, O. 2010. Examining pre-service chemistry teachers' pedagogical content knowledge and influences of Teacher course and practice school. *Journal of Science Education*, **11** (2), 76-79.

National Research Council (NRC), 2010. *Preparing teachers: Building evidence for sound policy*. National Academies Press: Washington, DC.

National Science Teachers Association. 2003. *The standards for science teacher preparation*. Retrieved May 25, 2016 from http://www.nsta.org/pdfs/NSTAstandards2003.pdf.

Naumescu, A.K. 2008. Science teacher competencies in a knowledge based society. *Acta Didactica Napocensia*, **1** (1), 25-31.

Nilsson, P. & Loughran, J. 2012. Exploring the development of pre-service elementary teachers' pedagogical content knowledge, *Journal of Science Teacher Education*, **23** (7), 699-721.

O'Donnell, C.L. 2008. Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K–12 curriculum intervention research. *Review of Educational Research*, **78** (1), 33-84.

Ogunniyi, M.B. & Rollnick, M. 2015. Pre-service Science Teacher Education in Africa: Prospects and Challenges. *J Sci Teacher Educ*, **26**, 65-79.

Olson, J.K., Tippett, C.D., Milford, T.M., Ohana, C. & Clough, M.P. 2015. Science Teacher Preparation in a North American Context. *Journal of Science Teacher Education*, **26**, 7-28.

Organisation for Economic Co-operation and Development (OECD). 2011. *Preparing teachers and developing school leaders for 21st century - lessons from around the world* (Background Report for the International Summit on the Teaching Profession).

Oskay, O.O., Erdem, E. & Yılmaz, A. 2009. Pre-service chemistry teachers' beliefs about teaching and their pedagogical content knowledge. *Hacettepe University Journal of Education*, **36**, 203-212.

Pajares, M.F. 1992. Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research*, **62**, 307–332.

Pallant, J. 2001. *SPSS Survival Manual*. Open University Press and McGraw-Hill Education: Maidenhead.

Palmer, D. 2008. Practices and innovations in Australian science teacher education programs. *Research in Science Education*, **38**, 167-188.

Panhwar, A.H., Ansari, S. & Shah, A.A. 2017. Post-positivism: an effective paradigm for social and educational research. *International Research Journal of Art & Humanities*, **45** (4), 253-259.

Park, S. & Oliver, J.S. 2008. Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education*, **38**, 261-284.

Reeves, C. & Major, T. 2012. Using student notebooks to measure opportunity to learn in Botswana and South African classrooms. *Prospects*, **42**, 403-413.

Reeves, C. & Muller, J. 2005. Picking up the pace: variation in the structure and organization of learning school mathematics. *Journal of Education*, **37**, 103-130.

Richardson, V. 1996. *The role of attitudes and beliefs in learning to teach*. In J. Sikula (Eds.), The handbook of research in teacher education (2nd ed., pp. 102-119). Macmillan: New York.

Rice, D.C. 2005. I didn’t know oxygen could boil! What preservice and inservice elementary teachers’ answers to ‘‘simple’’ science questions reveals about their subject matter knowledge. *International Journal of Science Education*, **27**, 1059-1082.

Richter, D., M. Kunter, U. Klusmann, O. Lüdtke, and J. Baumert. 2010. Professional development across the teaching career: Teachers' uptake of formal and informal learning opportunities*. Teaching and Teacher Education*, **27** (1), 116-26.

Rockoff, J. 2004. The impact of individual teachers on student ability: evidence from panel data. *Am Econ Rev*, **94** (2), 247-252.

Roehrig, G., & Luft, J. 2007. Capturing science teachers' epistemological beliefs: The development of the Teachers' Belief Interview. *Electronic Journal of Science Education*, **11** (2) 38-63.

Rogers, G. 2011. Learning-to-learn and learning-to-teach: The impact of disciplinary subject study on student-teachers' professional identity. *Journal of Curriculum Studies*, **43**, 249–268.

Ronfeldt, M. 2012. Where should student teachers learn to teach? Effects of field placement school characteristics on teacher retention and effectiveness. *Educational Evaluation and Policy Analysis*, **34**, 3-26.

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N. & Ndlovu, T. 2008. The place of subject matter knowledge in pedagogical content knowledge: a case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education*, **30** (10), 1365-1387.

Rollnick, M. & Mavhunga, E. 2014. PCK of teaching electrochemistry in chemistry teachers: A case in Johannesburg, Gauteng Province, South Africa. *Educación Química*, **25** (3), 354-362.

Rothstein, J. 2010. Teacher Quality in Educational Production: Tracking, Decay, and Student Achievement. *Quarterly Journal of Economics*, **125** (1), 175-214.

Roychoudhury, A. & Rice, D. 2013. Preservice secondary science teachers' teaching and reflections during a teacher education program. *International Journal of Science Education*, **35** (13), 2198-2225.

Russell, T. 2013. Has reflective practice done more harm than good in teacher education? *Phronesis*, **2**, 80-88.

Rusznyak, L. 2015. Knowledge selection in initial teacher education programmes and its implications for curricular coherence. *Journal of Education*, **60**, 7-29.

Ryder, J., Leach, J. & Driver, R. 1999. Undergraduate science students' images of science. *Journal of Research in Science Teaching,* **36** (2), 201-219.

Santau, A.O., Maerten-Rivera, J.L., Bovis, S. & Orend, J. 2014. A mile wide or an inch deep? Improving elementary preservice teachers' science content knowledge within the context of a science methods course. *Journal of Science Teacher Education*, **25**, 953–976.

Savasci-Acikalin, F. 2009. Teacher beliefs and practice in science education. *Asia-Pacific Forum on Science Learning and Teaching*, **10** (1), 1-14.

Savasci, F. & Berlin, D.F. 2012. Science Teacher Beliefs and Classroom Practice Related to Constructivism in Different School Settings. *Journal of Science Teacher Education*, **23**, 65-86.

Schneider, R.M. & Plasman, K. 2011. Science teacher learning progressions: A review of science teachers' pedagogical content knowledge development. *Review of Educational Research*, **81** (4), 530–565.

Schmidt, W.H., Cogan, L. & Houang, L. 2011. The role of opportunity to learn in teacher preparation: An international context. *Journal of Teacher Education,* **62** (2), 138-153.

Schmidt, W.H., Houang, R.T., Cogan, L., Blomeke, S., Tatto, M.T. Hsieh, F.J., Santillan, M., Bankov, K., Han, S.I., Cedillo, T., Schwille, J. & Paine, L. 2008. Opportunity to learn in the preparation of mathematics teachers: its structure and how it varies across six countries. *ZDM Mathematics Education,* **40**, 735-747.

Schmidt, W.H., McKnight, C.C., Houang, R.T., Wang, H.A., Wiley, D.E., Cogan, L.S., et al. 2001. *Why Schools Matter: A Cross-National Comparison of Curriculum and Learning.*: Jossey-Bass: San Francisco.

Schmidt, W.H., Wang, H.C. & McKnight, C.C. 2005. Curriculum coherence: an examination of US mathematics and science content standards from an international perspective. Journal of Curriculum Studies, **37** (5), 525-559.

Schwartz, M.S., Sadler, P.S., Sonnert, G.H. & Tai, R.H. 2009. Depth versus breadth: how content coverage in high school science courses relates to later success in college science coursework. *Science Education,* **93***,* 798-826.

Schwarz, C.V. & Gwekwerere, Y.N. 2007. Using a guided inquiry and modelling instructional framework (EIMA) to support preservice K-8 science teaching. *Science Education*, **91**, 158-186.

Shay, S. 2013. Conceptualizing curriculum differentiation in higher education: a sociology of knowledge point of view. *British Journal of Sociology of Education*, **34** (4), 563-582.

Shulman, L.S. 1986. Those who understand: Knowledge growth in teaching. *Educational Researcher*, **15** (2), 4-14.

Shulman, L. 1987. Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, **57** (1), 1-22.

Simmons, P., Emory, A., Carter, T., Coker, T., Finnegan, B. & Crockett, D. 1999. Beginning teachers: Beliefs and classroom actions. *Journal of Research in Science Teaching,* **36***,* 930-954.

Simonton, D.K. 2003. *Expertise, competence, and creative ability: the perplexing complexities*. In Sternberg RJ, Grigorenko E.L. (Eds), The psychology of abilities, competencies, and expertise (pp 213-239). Cambridge University Press, New York.

Smeby, J.C., & Heggen, K. 2014. Coherence and the development of professional knowledge and skills. *Journal of Education and Work*, **27**, 71-91.

Sorensen, P., Newton, L. & McCarthy, S. 2012. Developing a science teacher education course that supports student teachers' thinking and teaching about the nature of science. *Research in Science & Technological Education*, **30** (1), 29-47.

Stevenson, H.W., & Stigler, J.W. 1992. *The learning gap: Why our schools are failing and what we can learn from Japanese and Chinese education*. Summit Books: New York.

Sullivan, G.M. & Artino, A.R. 2013. Analyzing and interpreting data from Likert-type scales. *Journal of Graduate Medical Education*, **5**, 541-542.

Talanquer, V., Novodvorsky, I. & Tomanek, D. 2010. Factors influencing entering teacher candidates' preferences for instructional activities: A glimpse into their orientations towards teaching. *International Journal of Science Education,* **32** (10), 1389-1406.

Tanase, M. & Wang, J. 2010. Initial epistemological beliefs transformation in one teacher education classroom: Case study of four preservice teachers. *Teacher and Teacher Education,* **26**, 1238-1248.

Tatar, N. 2015. Pre-service teachers' beliefs about the image of a science teacher and science teaching. *Journal of Baltic Science Education*, **14**, (1), 34-44.

Tatto, M.T. 2007. *Reforming teaching globally* (Oxford Studies in Comparative Studies in Education). Symposium Books: Oxford, UK. Available online at http://www.symposium-books.co.uk/books/bookdetails.asp?bid=11

Tatto, M.T., Schwille, J., Senk, S., Ingvarson, L., Peck, R., & Rowley, G. 2008. Teacher Education and Development Study in Mathematics (TEDS-M): Policy, practice, and readiness to teach primary and secondary mathematics. Conceptual framework. Teacher Education and Development International Study Center, College of Education, Michigan State University: East Lansing, MI.

Tatto, M.T., Schwille, J., Senk, S., Ingvarson, L., Rowley, G., Peck, R., et al. 2012. *Policy, practice, and readiness to teach primary and secondary mathematics in 17 countries. Findings from the IEA teacher education and development study in mathematics (TEDS-M).* International Association for the Evaluation of Educational Achievement: Amsterdam, The Netherlands.

Taylor, N. 2014. *Initial Teacher Education Research Project: An examination of aspects of initial teacher education curricula at five higher education institutions*. Summary Report, JET Education Services: Johannesburg.

Thompson, N. & Pascal, J. 2012. Developing critically reflective practice. *Reflective Practice: International and Multidisciplinary Perspectives*, **13**, 311-325.

Tillotson, J.W. & Young, M.J. 2013. The IMPPACT project: A model for studying how preservice program experiences influence science teachers' beliefs and practices. *International Journal of Education in Mathematics, Science and Technology*, **1** (3), 148-161.

Tobias, S. 2010. *Science teaching as a profession: Why it isn't. How it could be*. Keynote presentation to the Association of Science Teacher Educators Annual International Meeting, Sacramento CA.

Tondeur, J., van Braak, J. Ertmer, P.A. & Ottenbreit-Leftwich, A. 2016. Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, 1-41.

Tornroos, J. 2005. Mathematics textbooks, opportunity to learn and student achievement. *Studies in Educational Evaluation*, **31**, 315-327.

Traianou, A. 2006. Teachers' adequacy of subject knowledge in primary science: Assessing constructivist approaches from a sociocultural perspective. *International Journal of Science Education*, **28** (8), 827-842.

Tretter, T.R., Brown, S.L., Bush, W., Saderholm, J. & Moore, B. 2007. *Valid and reliable physical, life, and earth science content assessments for middle school teachers*. Poster presented at the National Association for Research in Science Teaching Annual Conference, New Orleans, LA.

Turgut, H., Akçay, H. & İrez, S. 2010. The Impact of the Issue of Demarcation on Pre-service Teachers' Beliefs on the Nature of Science. *Educational Sciences: Theory & Practice*, 2654-2663.

Ucar, S. & Sanalan, V.K. 2011. How has reform in science teacher education programs changed preservice teachers' views about science? *Journal of Science Educational Technology*, **20**, 87–94.

Veal, W.R. 2004. Beliefs and knowledge in chemistry teacher development. *International Journal of Science Education,* **26** (3), 329-351.

Verloop, N., van Driel, J. & Meijer, P. 2001. Teacher knowledge and the knowledge base of teaching. *International Journal of Educational Research,* **35**, 441-461.

Vetters, A.M. & Reynolds, J. 2012. Lessons from a preservice teacher: Examining missed opportunities for multicultural education in English education program. *Networks*, **14** (1), 1-10.

Wallace, S. 2009*. A Dictionary of education*. Oxford University Press: Oxford.

Wallace C.S. 2014. *Overview of the Role of Teacher Beliefs in Science Education*. In Evans et al. (Eds), The Role of Science Teachers' Beliefs in International Classrooms (pp. 17–34). Sense publishers: Rottendam.

Wallace, C.S. & Kang, N. 2004. An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching*, **41**, 936-960.

Wang, J. 1998. Opportunity to Learn: The Impacts and Policy Implications. *Educational Evaluation and Policy Analysis*, **20** (3), 137-156.

Wasserman, N.H. & Walkington, C. 2014. Exploring links between beginning UTeachers' beliefs and observed classroom practices. *Teacher Education and Practice,* **27** (2/3), 376-401.

Weinert, F. 2001. *Concept of competence: a conceptual clarification*, in Rychen, D. and Salganik, L. (eds), Defining and Selecting Key Competencies (pp. 45-66). Seattle.

Weizman, A., Covitt, B. A., Koehler, M. J., Lundeberg, M. A., Oslund, J. A., Low, M. A, Eberhardt, J. & Urban-Lurain, M. 2008. Measuring teachers' learning from a problem-based learning approach to professional development in science education. *Interdisciplinary Journal of Problem-based Learning*, **2** (2), 29–60.

Wilson, S.M. 2011. *Effective STEM teacher preparation, induction, and professional development. In commissioned paper presented at the Workshop on Successful STEM*

Education in K-12 Schools. Board on Science Education, The National Academies of Science. Washington, DC.

Wilson, S., Floden, R., & Ferrini-Mundy, J. 2001. Teacher preparation research: an insider's view from the outside. *Journal of Teacher Education*, **53** (3), 190-204.

Wilson-VanVoorhis C.R. & Morgan, B.L. 2007. understanding power and rules of thumb for determining sample sizes. *Tutorials in Quantitative Methods for Psychology*, **3** (2), 43-50.

Windschitl, M. 2009. *Cultivating 21st century skills in science learners: How systems of teacher preparation and professional development will have to evolve*. National Academies of Science Workshop on 21st Century Skills. Washington, DC.

Yager, R.E., & Apple, M.A. 1993. *Linking Teacher Preparation Outcomes and Teacher Performance* (A proposal prepared for the U.S. Department of Education). The University of Iowa, Science Education Center: Iowa City, IA.

Yilmaz-Tuzan, O. & Topcu, M.S. 2008. Relationships among preservice science teachers' epistemological beliefs, epistemological world views and self-efficacy beliefs. *International Journal of Science Education,* **30** (1), 65-85.

Yuen, L.H. 2011. Early childhood teacher learning through a professional development school program in Hong Kong, *Journal of Early Childhood Teacher Education*, **32** (1), 72-83.

Zhao, Y. 2010. Preparing Globally Competent Teachers: A New Imperative for Teacher Education. *Journal of Teacher Education,* **61** (5), 422-431.

Zeichner, K. 2005. A research agenda for teacher education. In M. Cochran-Smith & K. Zeichner (Eds.), *Studying Teacher Education: The Report of the AERA Panel on Research and Teacher Education* (p. 737-759). Lawrence Earlbaum Associates: Mahwah, NJ.

Zeichner, K. 2010. Rethinking the connections between campus courses and field experiences in college- and university-based teacher education. *Journal of Teacher Education*, **61** (1–2), 89-99.

Appendix 1: The questionnaire

Pre-Service Teacher Questionnaire

Please note that the questionnaire consists of four sections.

- Section 1: Pre-service teacher knowledge (content and pedagogical content knowledge, 25 minutes)
- Section 2: Pre-service teacher beliefs (10 minutes)
- Section 3: Opportunities to lean (20 minutes)
- Section 4: General information (5 minutes)

Please answer the sections to the best your knowledge and/or ability.

References:

Mahlomaholo, S., Letsie, L., Tlali, M., Letloenyane, M., Mosia, M., Janqueira, K., du Toit, S., Papashane, M., Chele, T. & Tshabalala, S. (2014). *Teaching and Learning Deficiencies in Physical Science, Mathematics and English in the North-West Dinaledi Schools: A Strategy for Improvement*. Bloemfontein, University of the Free State.

Tatto, M. T., Schwille, J., Senk, S., Ingvarson, L., Peck, R., & Rowley, G. (2008). *Teacher Education and Development Study in Mathematics (TEDS-M): Policy, practice, and readiness to teach primary and secondary mathematics. Conceptual framework*. East Lansing, MI: Teacher Education and Development International Study Center, College of Education, Michigan State University.

Section 1: Teacher knowledge (content and pedagogical content knowledge)

1. Neil Armstrong is standing on the surface of the moon holding a cricket ball 2 meters above the surface. The teacher asks what will happen to the ball if Neil lets go of the ball. Which explanation from the learners is correct?

   a. The ball and the moon will repel each other and the ball will move away from the moon
   b. The ball will continue to float at 2 meters as there is no gravity on the moon.
   c. The gravity of the moon will pull the ball towards the surface with gravitational acceleration less than that of the earth.
   d. The ball will start orbiting the moon.

2. The Apollo is in orbit around earth when one of the astronomers sees a big explosion in Johannesburg. The astronomer sees the explosion but is unable to hear the sound caused by the explosion. Lesego thinks it is because there is no medium in space for the sound to travel in. Is this line of thinking correct?

   a. No, the sound will be scattered completely by the atmosphere
   b. Yes, Sound cannot travel in vacuum
   c. No, Sound does not have enough energy to travel through space
   d. No, the sound waves will be reflected by the atmosphere

3. A learner standing on top of a hill looking towards the horizon sees some dark clouds. He suddenly sees a flash of lightning and hears the rumble of the thunder seconds later. He later explains to his teacher that light is significantly faster than sound so you will see the lightning first, and hear the thunder later. Is the learner's explanation correct?

   a. Yes, the student is correct.
   b. No, sound must travel longer distance than lightning
   c. No, the lightning must strike the earth first and only then do you hear the sound.

4. Learners are having a discussion concerning sound. Kenny thinks the loudness of a sound wave is dependent on the medium of propagation. In correcting Kenny, the teacher explains loudness in real life context. Which one is the best explanation?

a. If you increase the volume of your radio, it becomes louder because the amplitude of the wave is increased.

b. If you increase the volume of your radio, it becomes louder because the frequency of the wave is increased.

c. If you increase the volume of your radio, the waves interfere constructively; therefore, the sound is louder.

d. If you increase the volume of your radio, the speaker produces more waves and consequently, the sound is higher

5. Learners are having an argument about the meaning of coherence and they take the matter to the teacher. Which one of the following best describes "coherence"?

a. The polarization state of two waves.

b. The phase relationship between two waves.

c. The diffraction of two waves.

d. The sources distance between two waves.

6. On a hot day, Thabo notices droplets of water on the sides of his cold glass of juice. Which one of the following statements is true regarding these droplets of water?

a. The droplets are caused by water molecules that leak through the container

b. The droplets are caused by water vapour from the air that comes in contact with the container.

c. The droplets are caused by moisture from Thabo hands

d. None of the above

7. In a discussion about photoelectric effect, Lerato says that light intensity has an effect on the amount of electrons. To correct this misconception, the teacher should:

a. Tell Lerato she is wrong and tell her the right answer

b. Use a simulator (on a computer) to show her line of thinking is not correct

c. Ask her to look for the answer in her text book.

d. Take the photoelectric effect apparatus and carry out an experiment to correct her misconception

8. A practical way of introducing forces (Newton's second law) for learners is to have a learner pull a trolley with little friction while another sits on it. Which of one of the following approaches is best suited for fostering inquiry in learners?

a. You dictate the law to learners and explain it by drawings on the board, then you let the pull the trolley to test the forces required for constant speed.

b. You first let the learners pull the trolley at constant speed, then guide the learner to the law by asking questions and affording them the opportunity to deduce their own laws before explaining the correct law

c. You first define acceleration and link it to Newton's second law by using examples relating acceleration to net force and then you let learners experience it by playing with a trolley.

d. You let the learners read the law in the text book encouraging them to ask question where they do not understand and then you demonstrate the law in front of the class using the trolley.

9. In an introductory lesson about electricity, the teacher starts by explaining electricity and how it works then provides definitions to important terms. Which one of the following best describes the lesson?

a. The lesson is going well because the teacher is providing a good base for the learner's future studies of electricity.

b. The lesson is going well because learners will be in a position to ask questions where they do not understand.

c. The lesson is not going well because the teacher is not engaging the learners.

d. The lesson is not going well because the teacher missed an opportunity to find out learners conceptions about electricity.

10. Identify the statement that correctly explains Boyle's Law:

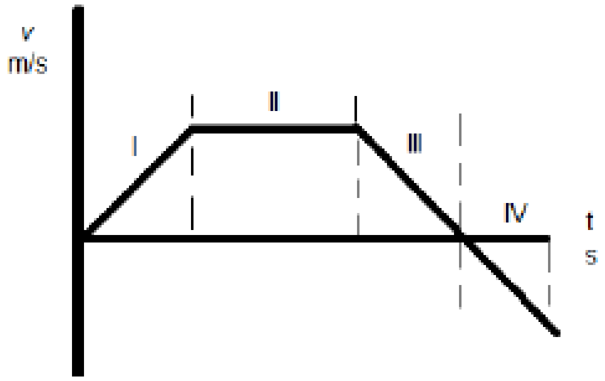
a. The volume of a certain amount of gas is directly proportional to the temperature of that gas in any situation.

b. The volume of a certain amount of gas is directly proportional to the temperature of that gas as long as the pressure remains constant.

c. The pressure exerted by a certain amount of gas is inversely proportional to the volume of that gas as long as the temperature remains constant.

d. The pressure exerted by a certain amount of gas is directly proportional to the volume of that gas as long as the temperature remains constant.

11. The graph below is a velocity-time graph. On which section(s) of the graph is the car moving in the negative direction?



a. III and IV, because the slope in both sections will be negative

b. III only, because in section III the car turns and heads in the opposite direction

c. IV only, because the velocity is negative and the car must be heading in the negative direction

d. The car never moves in the negative direction

12. You suspect that your students have misconceptions about "weightlessness" and you ask them why Astronauts on the orbiting space station are *weightless*. Which one of the following responses do you agree with?

a. There is no gravity in space and they do not weigh anything.

b. Space is a vacuum and there is no gravity in a vacuum.

c. All contact forces on their bodies are removed.

d. The astronauts are far from Earth's surface at a location where gravitation has minimal effect.

13. Atlegang is observing water boil in a glass beaker; she deduces that bubbles rising from the bottom are caused by air. Does Atlegang fully understand the concept of phase change?

a. Yes, because bubbles rising are air bubbles

b. No, because bubbles rising are caused by the breaking down of water into hydrogen and oxygen

c. Partially, the bubbles rising are caused by air and water vapour

d. No, the bubbles rising are caused by water vapour

14. Lindiwe carries out the following reaction in a glass beaker in the laboratory:

$$NaHCO_3\,(s) + CH_3COOH(l) \rightarrow CH_3COONa(aq) + CO_2(g) + H_2O$$

She measures the mass of the beaker and the reactants before the commencement of the reaction. After two hours she measures the mass of the beaker and contents again and notices that the mass of the beaker and contents is less than the mass of the beaker and reactants before the reaction commenced. Since she knows of mass conservation, she asks the teacher for an explanation. Which one the following explanations from the teacher is correct?

a. As the reaction progressed, heat was given off and the mass of the contents decreased.
b. As the reaction progressed, reactants reacted and formed products, the products will always be less than the reactants
c. As the reaction progressed, heat was given off and the beaker started to shrink.
d. As the reaction progressed, $CO_2(g)$ was formed and bubbled out of solution. There is a reduction in mass of contents and beaker because of the loss of $CO_2(g)$.

15. Lehlohonolo is arguing with Thabang over what will happen to the reducing agent in an electrochemical reaction. The teacher gives them the options below and asks them to discuss amongst the whole class the best answer. Which one must the learners choose?

a. It is oxidized as it gains electrons
b. It is reduced as it gains electrons
c. It is reduced as it loses electrons.
d. It is oxidized as it loses electrons.

16. During a lesson about atoms, Lebohang is confused by the particles that contribute mostly to the mass of the atom. In trying to assist him with his thinking about the problem, the teacher should:

a. Tell him that protons and neutrons contribute mostly to the mass of the atom
b. Ask him to pick an element and calculate the number of neutrons and guide him to think about molar mass, protons and neutrons.
c. Tell him to think about the atomic mass of an element
d. Tell him to figure out which one is the heaviest between neutrons and protons

17. Learner's worked on a kinetics experiment and collected data in groups. In a discussion with the whole class, one group's data seems not to be consistent with data from the whole class. How would you handle this situation?

a. Tell the class which group's data is correct so that they do not get any wrong ideas about kinetics
b. Ask the learners to find a way of resolving the issue by having the group with the inconsistent data explain how they gathered the data
c. Ask the learners to vote for the data they think is more accurate, this will help justify the consistent data
d. Ask the learner's to read through the textbook to try and identify what could have gone wrong with the inconsistent data.

18. Your students are uncertain about which of the changes I and II will shift the following equilibrium to the right. What do you tell them?

$2SO_2(g) + O_2(g)$ <---> $2SO_3(g)$ for which $\Delta H < 0$.

I increasing the temperature

II Increasing the volume of the container

a. I only
b. II only
c. Both I and II
d. Neither I nor II

19. Consider these two reactions, occurring at the same temperature;

Reaction 1: C (g) + P (g) → B (g) Δ H < 0 **(Exothermic)**

Reaction 2: G (g) + V (g) → Q (g) Δ H > 0 **(Endothermic)**

On the basis of this information some students are comparing the rates of these two reactions.

Serap says:" Reaction 1 is faster, because exothermic reactions occur faster than endothermic reactions."

Minnie says: "The rates of these reactions are the same, because they occur at the same temperature"

Burcu disagrees: "No, it is not possible to compare the rates of these reactions, because there is not enough information given in the question"

Whom do you agree with?

a. Serap
b. Mine
c. Burcu

d. None

Questions 30 to 32 are based on the following scenario:
***An educator, Ms. Tsoho, is to prepare for the facilitation of an introductory lesson based on the classification of matter to the grade 10 Physical Sciences classes.* Ms. Tsoho is uncertain about the best possible approach in respect of whether to start with mixtures or pure substances or to integrate the two in her teaching or learning facilitation.**

20. Which one of the following statements best describes your advice to Ms. Tsoha regarding her lesson plan and lesson?

    a. The lesson should commence with an appropriate prior knowledge test *e.g.* regarding learners' understanding of matter, states/phases of matter, physical and chemical properties of matter.
    b. The teacher should indicate her lesson objectives to the class at the beginning of the lesson before she conducts a pre knowledge test.
    c. The teacher should first indicate the lesson objectives to the class at the beginning of the lesson thereafter she should engage in learners' pre knowledge test, then a practical lesson presentation and finally assess the extent of achievement of the lesson objectives.
    d. Present different types of mixtures to learners, let the learners identify the respective components of the mixtures discuss the findings with them to address their misconceptions about matter.

21. Among the mixtures that Ms. Tsoho brought to class were: glass of fresh milk, cup of black coffee (which she poured out from her flask) and salty water. Which of the following arguments regarding the learners' descriptions of fresh milk should Ms. Tsoho consider as the best possible description(s)?

    a. Fresh milk is a homogeneous solution because it is a uniform, white liquid. It is also a pure substance.
    b. Fresh milk is a heterogeneous mixture. The white colour of the milk is the small solid fat particles which occupy the spaces between the particles of the water liquid.
    c. Fresh milk is a homogeneous solution because it is a uniform, white liquid. It is not a pure substance because it comprises of different compounds.
    d. Fresh milk has the characteristics of both a homogeneous and a heterogeneous solution. It is therefore a heterogeneous solution.

22. After the class, some learners decide to pour some soil into a beaker of salty water and it became brownish after stirring the contents. One of them asserts that the soil solution is a homogeneous solution. Which of the following statement is correct in this instance?

a. yes, the solution is homogenous

b. no, the solution is heterogeneous

c. no, the solution is a mixture of homogenous and heterogeneous solutions

d. no, the solution cannot be described in this manner

23. The nucleus in an atom is said to be surrounded by a cloud of electrons, what is meant by this statement?

a. The cloud is like rain cloud with electrons suspended like water droplets

b. The cloud contains electrons but is made up of something else

c. The cloud of electrons is similar to the sea of electrons in metals

d. The electrons are constantly moving around the cloud but the cloud is not made up by another kind of matter.

24. As an introduction to equilibrium, the teacher asks the learners to identify which one of the following is a good example of a dynamic equilibrium. Which of the following is the best answer?

a. Beaker of alcohol sitting on a counter at room temperature

b. Kettle of water boiling at a constant rate

c. Gas burning in a home furnace

d. Unopened can of coke sitting on a grocery shelf

Section 2: Beliefs

1. Beliefs about the nature of physical science

To what extent do you agree or disagree with the following beliefs about the nature of physical science? **(Tick one box in every row: 1- Strongly disagree; 2 - disagree; 3 – Slightly disagree; 4 – Slightly agree; 5 – Agree; 6 – Strongly agree)**

A. Physical science is a collection of rules and theories that control the universe	1	2	3	4	5	6
B. Physical science involves the remembering and application of definitions, formulas, facts and calculations.	1	2	3	4	5	6
C. Physical science involves creativity and new ideas.	1	2	3	4	5	6
D. In physical science many things can be discovered and tried out by one's self.	1	2	3	4	5	6
E. Fundamental to physical science is generation of knowledge and facts	1	2	3	4	5	6
F. To do physical science requires much practice, correct application of laws, and problem solving strategies.	1	2	3	4	5	6

2. Beliefs about learning physical science

From your perspective, to what extent would you agree or disagree with each of the following statements about learning physical science? **(Tick one box in every row: 1- Strongly disagree; 2 - disagree; 3 – Slightly disagree; 4 – Slightly agree; 5 – Agree; 6 – Strongly agree)**

A. The best way to do well in physical science is to memorize all the theories and laws.	1	2	3	4	5	6
B. Learners need to be taught exact procedures for solving physical science problems.	1	2	3	4	5	6
C. It doesn't really matter if you understand a physical science problem, if you can get the right answer.	1	2	3	4	5	6
D. In addition to getting a right answer in physical science, it is important to understand why the answer is correct.	1	2	3	4	5	6
E. Non-standard procedures and processes should be discouraged because they can interfere with learning the correct procedures and processes.	1	2	3	4	5	6
F. Hands-on physical science experiences aren't worth the time and expense.	1	2	3	4	5	6

3. Beliefs about physical science achievement

To what extent do you agree or disagree with each of the following statements about learner achievement in secondary school physical science? **(Tick one box in every row: 1- Strongly disagree; 2 - disagree; 3 – Slightly disagree; 4 – Slightly agree; 5 – Agree; 6 – Strongly agree)**

A. Since older learners can reason abstractly, the use of hands-on models and other visual aids becomes less necessary.	1	2	3	4	5	6
B. Physical science is a subject in which natural ability matters a lot more than effort.	1	2	3	4	5	6
C. In general, boys tend to be naturally better at Physical science than girls.	1	2	3	4	5	6
D. Physical science ability is something that remains relatively fixed throughout a person's life.	1	2	3	4	5	6
E. Some people are good at physical science and some aren't.	1	2	3	4	5	6
F. Some ethnic groups are better at physical science than others.	1	2	3	4	5	6

4. Beliefs about preparedness for teaching physical science

Please indicate the extent to which you think your teacher education program has prepared you to do the following when you start your teaching career. **(Tick one box in every row: 1- Not at all; 2 – A minor extant; 3 – A modest extent; 4 – A major extent)**

A. Establish appropriate learning goals in physical science for learners	1	2	3	4
B. Set up physical science learning activities to help learners achieve learning goals	1	2	3	4
C. Use questions to promote higher order thinking in physical science	1	2	3	4
D. Use computers and ICT to aid in teaching physical science	1	2	3	4
E. Challenge learners to engage in critical thinking about physical science	1	2	3	4
F. Establish a supportive environment for learning physical science	1	2	3	4
G. Use assessment to give effective feedback to learners about their physical science learning	1	2	3	4
H. Develop assessment tasks that promote learning in physical science	1	2	3	4
I. Use assessment to give effective feedback to learners about their physical science learning	1	2	3	4
J. Have a positive influence on difficult or unmotivated learners	1	2	3	4

5. **Beliefs about programme effectiveness**

To what extent do you agree or disagree with the following statements? The instructors who teach physical science-related courses in your current teacher preparation program: **(Tick one box in every row: 1- Strongly disagree; 2 - disagree; 3 – Slightly disagree; 4 – Slightly agree; 5 – Agree; 6 – Strongly agree)**

A. Model good teaching practices in their teaching	1	2	3	4	5	6
B. Draw on and use research relevant to the content of their courses	1	2	3	4	5	6
C. Model evaluation and reflection on their own teaching	1	2	3	4	5	6
D. Value the learning and experiences you had prior to starting the program	1	2	3	4	5	6
E. Value the learning and experiences you had in your field experience and or practicum	1	2	3	4	5	6
F. Value the learning and experiences you had in your teacher preparation program	1	2	3	4	5	6

Section 3: Opportunities to learn

1. ***Tertiary level** physics and chemistry*

Consider the following topics in university level physics and chemistry. Please indicate whether you have ever studied each topic at. (**1**-Yes; **2**-No)

Physics		
A. **Motion along a straight line** (position, displacement, velocity, acceleration)	1	2
B. **Motion in two or three dimension** (Vectors, average velocity, acceleration, projectile motion, uniform circular motion)	1	2
C. **Force and motion** (mass, force, Newtonian laws, friction, terminal speed)	1	2
D. **Kinetic energy and Work** (Kinetic energy, kinetic energy and work, gravitational force and work, spring force and work, work done by variable force)	1	2
E. **Potential energy and conservation of energy** (Work and potential energy, mechanical energy, conservation of energy, work done by/on a system,	1	2
F. **Center of mass and linear motion** (linear momentum, collision and impulse, conservation of linear momentum, collision in two dimensions)	1	2
G. **Rolling, rotation, torque and angular momentum** (rotational variables, kinetic energy and rotation, torque, angular momentum, gyroscopes)	1	2
H. **Gravitation** (Laws of gravitation, gravitation and superposition, gravitation near and inside the earth, Kepler's laws, Einstein and gravitation	1	2
I. **Fluids** (density and pressure, fluids at rest, Pascal's principle, Archimedes principle, fluids in motion, Bernoulli's equation)	1	2
J. **Oscillations and Waves** (Simple harmonic motion, pendulums, forced oscillations and resonance, types of waves, wavelength, Doppler effect)	1	2
K. **Temperature, heat and laws of thermodynamics** (Celsius and Fahrenheit scales, laws of thermodynamics, thermal expansion, heat and work, entropy)	1	2
L. **Kinetic theory of gases** (Avogadro's number, ideal gases, pressure, rms speed, temperature, molar specific heat, quantum theory, adiabatic expansions)	1	2
M. **Electric fields and charges** (field lines, electric fields due to point charges and electric dipoles, electric charges, coulombs law, conservation of charges)	1	2
N. **Gaussian laws** (flux of electric field, Gauss laws and its applications)	1	2
O. **Current, resistance and capacitance** (equipotential surfaces, electric current, resistance and resistivity, Ohm's law, semi and super conductors)	1	2
P. **Circuits, Magnetic fields and inductance** (Work, energy, emf, circuits ammeters and voltmeters, Hall effect, solenoids, RC circuits, induced electric field, Alternating current.)	1	2
Q. **Maxwell equations, electromagnetic waves** (magnetism and electrons, images, interference, diffraction)	1	2
R. **Relativity, photons and matter waves** (effects of relativity, photoelectric effect, Schrodinger's equations, Bohr's model of an atom, Heisenberg principle)	1	2
S. **Atoms and nuclear physics** (properties of atoms, semiconductors, properties of the nucleus, energy form the nucleus)	1	2

T. **Quarks, leptons and the big bang** (The quark model, messenger particles, big bang)	1	2

Chemistry		
A. **Atoms, molecules and ions** (atomic theory and structure, chemical substances: formulas and names, chemical reactions: equations)	1	2
B. **Chemical reactions** (Aqueous solutions, types of chemical reactions, balancing of chemical reactions)	1	2
C. **Calculations with chemical formulas and equations** (mass and moles of substances, determining chemical formulae, stoichiometry, quantitative analysis)	1	2
D. **Gaseous state** (Empirical gas law, ideal gas law, gas mixtures Kinetic molecular theory)	1	2
E. **Thermodynamics** (Understanding heats of reactions, enthalpy, thermo-chemical reactions, Hess law, standard enthalpies of reaction.)	1	2
F. **Quantum theory of the atom** (light waves, protons, Bohr theory, quantum mechanics and quantum numbers, atomic orbital)	1	2
G. **Electron configuration and periodicity** (electric structure of the atom, orbital diagrams of atoms, periodicity of the elements, Mendelev predictions)	1	2
H. **Ionic and covalent bonding** (ionic bonding, covalent bonds, Lewis structures and dot formulae)	1	2
I. **Molecular geometry and chemical bonding theory** (molecular geometry, VSEPR model, molecular orbital theory, electron configurations	1	2
J. **States of matter** (changes of state, liquid state, properties of liquids, intermolecular forces, solid state, crystal structures)	1	2
K. **Solutions** (Solution formation, colligative properties, boiling point elevation, freezing point depression, colloid formation)	1	2
L. **Rates of reactions** (reaction rates, dependence of the rate of reactions, reaction mechanisms, the rate law, catalysis)	1	2
M. **Chemical equilibrium** (Describing chemical equilibrium, the equilibrium constant, Le Chatelier's principle)	1	2
N. **Acids and bases** (acid-base concepts, acid base strengths, self-ionization of water, pH)	1	2
O. **Acid-base equilibria** (solutions of weak acids and base, solutions of weak acid or base with another solute)	1	2
P. **Solubility and complex-ion equilibria** (solubility equilibria, complex ion equilibria, applications of solubility equilbria	1	2
Q. **Electrochemistry** (Half reactions, voltaic cells, electrochemistry, emf and pH sensors	1	2
R. **Nuclear chemistry** (radioactivity and nuclear bombardment reactions, energy of nuclear reactions)	1	2
S. **Metallurgy and main group elements**	1	2
T. **Organic chemistry** (Hydrocarbons, derivatives of hydrocarbons, mechanism, spectroscopy)	1	2

2. ***<u>School level</u> physical science***

Consider the following topics in school level physical science. Please indicate whether you have ever studied each topic at your university. Tick one box in each row (**1-Yes; 2-No**)

Physical science		
A. **Vectors & scalars: Motion in one dimension** (reference frame, displacement and distance, average velocity, acceleration, instantaneous velocity)	1	2
B. **Newton's Laws and Application of Newton's Laws** (Newton's first, second and third laws and Newton's law of universal gravitation, different kinds of forces)	1	2
C. **Momentum and Impulse** (momentum, Newton's second law, conservation of momentum, elastic and inelastic collisions, Impulse)	1	2
D. **Vertical projectile motion in one dimension (1D)** (vertical projectile motion represented in words, diagrams, equations and graphs)	1	2
E. **Work, Energy & Power** (work, work-energy theorem, conservation of energy with non-conservative forces present, power)	1	2
F. **Transverse and Longitudinal waves** (wavelength, frequency, amplitude, period, wave speed, sound waves, pitch, loudness, quality (tone), ultrasound)	1	2
G. **Electromagnetic radiation** (dual (particle/wave) nature of electromagnetic (EM) radiation, nature of EM radiation, EM spectrum	1	2
H. **Geometrical Optics, 2D & 3D Wave fronts** ((Refraction, Snell's Law, Critical angles and total internal reflection, Diffraction, **Doppler Effect**)	1	2
I. **Magnetism and Electrostatics** (magnetic field, attraction and repulsion, field lines, earth's magnetic field, two kinds of charge, force exerted by charges	1	2
J. **Electric circuits and electrodynamics** (emf, potential difference, current, resistance, resistors in parallel and series, electrical machines, alternating current)	1	2
K. **States of matter and the kinetic molecular theory** (materials, models of the atom; atomic mass; protons, neutrons and electrons; isotopes)	1	2
L. **Physical and chemical change** (separation by physical & chemical means; conservation principle; law of constant composition names and formulas).	1	2
M. **Molecular structure and Intermolecular forces** (a chemical bond; molecular shape; electronegativity and bond polarity, states of matter; density; kinetic energy)	1	2
N. **Ideal gases** (motion and kinetic theory of gases; gas laws; relationship between T and P)	1	2
O. **Atomic structure and Chemical bonding** (models of the atom; atomic mass and diameter; protons, neutrons and electrons, covalent, ionic & metallic bonding)	1	2
P. **Optical phenomena and properties of materials** (photo-electric effect, emission and absorption spectra)	1	2
Q. **Organic chemistry** (functional groups; saturated and unsaturated structures; isomers; naming and formulae; physical properties; chemical reactions	1	2
R. **Stoichiometry** (molar volume of gases; concentration; limiting reagents; volume relationships in gaseous reactions)	1	2
S. **Reaction rate & Chemical equilibrium** (factors affecting rate; mechanism of reaction and of catalysis, factors affecting equilibrium; equilibrium constant)	1	2
T. **Electrochemical reactions** (electrolytic and galvanic cells; relation of current and potential to rate and equilibrium; standard electrode potentials; oxidation)	1	2
U. **Acids and bases** (reactions; titrations, pH, salt hydrolysis)	1	2

6. In your current teacher preparation program, how frequently did you engage in activities that gave you the opportunity to learn how to do the following? (**Tick one box in every row: 1- Never; 2 - Rarely; 3 - Occasionally; 4 – Often**)

A. Accommodate a wide range of abilities in each lesson	1	2	3	4
B. Analyse pupil assessment data to learn how to assess more effectively	1	2	3	4
C. Assess higher–level goals (e.g., problem-solving, critical thinking)	1	2	3	4
D. Assess low–level objectives (factual knowledge, routine procedures and so forth)	1	2	3	4
E. Create learning experiences that make the central concepts of subject matter meaningful to learners	1	2	3	4
F. Deal with learning difficulties so that specific pupil outcomes are accomplished	1	2	3	4
G. Develop instructional materials that build on learners' experiences, interests and abilities	1	2	3	4
H. Help learners learn how to assess their own learning	1	2	3	4
I. Use learners' misconceptions to plan instruction	1	2	3	4
J. Integrate physical science ideas from across areas of science	1	2	3	4

9. In your teacher preparation program, how often did you have the opportunity to learn to do the following? (**Tick one box in every row: 1- Never; 2 - Rarely; 3 - Occasionally; 4 – Often**)

A. Develop research projects to test teaching strategies for learners of diverse abilities	1	2	3	4
B. Consider the relationship between education, social justice and democracy	1	2	3	4
C. Identify appropriate resources needed for teaching	1	2	3	4
D. Observe teachers modelling new teaching practices	1	2	3	4
E. Develop and test new teaching practices	1	2	3	4
F. Set appropriately challenging learning expectations for learners	1	2	3	4
G. Learn how to use findings from research to improve knowledge and practice	1	2	3	4
H. Connect learning across subject areas	1	2	3	4

I. Create methods to enhance learners' confidence and self-esteem	1	2	3	4
J. Identify opportunities for changing existing schooling practices	1	2	3	4

11. For what proportion of this time were you temporarily in charge of teaching the class (as opposed to observation, assistance, and individual tutoring)? **Tick one box**

A. Less than ¼ of the time	1
B. ¼ or more, but less than ½	2
C. ½ or more, but less than ¾	3
D. ¾ or more	4

12. For about how much of the time in the field experience, was one of your assigned mentors present in the same room as you? **Tick one box**

A. Less than ¼ of the time	1
B. ¼ or more, but less than ½	2
C. ½ or more, but less than ¾	3
D. ¾ or more	4

14. To what extent do you agree or disagree with the following statements about the field experience you had in your teacher preparation program? **(Tick one box in every row: 1- Disagree; 2 – Slightly disagree; 3 – Slightly agree; 4 – Agree)**

A. I had a clear understanding of what my school-based mentor expected of me as a teacher in order to pass the field experiences.	1	2	3	4
B. My school-based mentor valued the ideas and approaches I brought from my university teacher education program.	1	2	3	4
C. My school-based mentor used criteria provided by my university when reviewing my lessons with me.	1	2	3	4
D. In my field experience I had to demonstrate to my supervising teacher that I could teach according to the same criteria used in my university course.	1	2	3	4
E. The feedback I received from my mentor helped me improve my teaching methods.	1	2	3	4
F. The feedback I received from my mentor helped me improve my knowledge of physical science content.	1	2	3	4

G. The methods of teaching I used in my field experiences were quite different from the methods I was learning in my university course.	1	2	3	4
H. The regular supervising teacher in my field experiences classroom taught in ways that were quite different from the methods I was learning in my university course.	1	2	3	4

15. Coherence of your teacher education programme
Consider all of the courses in the program including subject matter courses (e.g., physical science), physical science pedagogy courses, and general education pedagogy courses. Please indicate the extent to which you agree or disagree with the following statements. (**Tick one box in every row: 1- Disagree; 2 – Slightly disagree; 3 – Slightly agree; 4 – Agree**)

A. Each stage of the program seemed to be planned to meet the main needs I had at that stage of my preparation.	1	2	3	4
B. Later courses in the program built on what was taught in earlier courses in the program.	1	2	3	4
C. The program was organized in a way that covered what I needed to learn to become an effective teacher.	1	2	3	4
D. The courses seemed to follow a logical sequence of development in terms of content and topics.	1	2	3	4
E. Each of my courses was clearly designed to prepare me to meet a common set of explicit standard expectations for beginning teachers.	1	2	3	4
F. There were clear links between most of the courses in my teacher education program.	1	2	3	4

Section 4: Background information

These are general questions about the participant. Please mark the appropriate box with X

1. What is your gender?

Male	1
Female	2

2. What is your age? (in years)

Under 25	25 – 29	30 – 39	40 – 49	50 – 59	60+
1	2	3	4	5	6

3. Are you already employed at a school?

Yes	1
No	2

4. If employed, for how long?

Under a year	2 – 4yrs	5 – 9yrs	10-19yrs	20 – 40yrs
1	2	3	4	5

5. What is your highest qualification?

No qualification	Bachelors degree	Higher certificate	Honours	Masters	Doctorate
1	2	3	4	5	6

If the qualification is not in education, please specify the qualification

____

6. Did you have physical science up to grade 12?

Yes	1
No	2

Thank you for your participation

Appendix 2: Ethical clearance / approval letters

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA

UFS·UV
EDUCATION
OPVOEDKUNDE

Faculty of Education

15-Jun-2016

Dear Mr **David Letloenyane**

Ethics Clearance: **Science teacher preparation: An assessment of the opportunities to learn and their effects on pre-service teachers' competence.**

Principal Investigator: **Mr David Letloenyane**

Department: **School of Education Studies (Bloemfontein Campus)**

APPLICATION APPROVED

With reference to you application for ethical clearance with the Faculty of Education, I am pleased to inform you on behalf of the Ethics Board of the faculty that you have been granted ethical clearance for your research.

Your ethical clearance number, to be used in all correspondence is: **UFS-HSD2016/0627**

This ethical clearance number is valid for research conducted for one year from issuance. Should you require more time to complete this research, please apply for an extension.

We request that any changes that may take place during the course of your research project be submitted to the ethics office to ensure we are kept up to date with your progress and any ethical implications that may arise.

Thank you for submitting this proposal for ethical clearance and we wish you every success with your research.

Yours faithfully

Dr. Juliet Ramohai

March 10, 2017

Mr Maleho (DM) Letloenyane
Faculty / Fakulteit: Education
University of the Free State
letloenyanemd@ufs.ac.za

Dear Mr Letloenyane

Approval from the Registrar's Office to Conduct Research

Having consulted the Chairperson of the Research Ethics Committee, I hereby grant permission for Mr Letloenyane to conduct research relating to his thesis "Science Teacher Preparation: An assessment of the opportunities to learn and their effects on pre-service teacher competence".

We look forward to reading the research report.

Kind regards

Prof M Somniso
Institutional Registrar

Mr D Letloenyane
C/o Prof LC Jita
School of Education Studies (Bloemfontein Campus)
Faculty of Education
University of the Free State

Dear Mr Letloenyane,

Decision: Final Approval

Name: Letloenyane D
Project title: *Science teacher preparation: An assessment of the opportunities to learn and their effects on pre-service teachers' competence*
Qualification: PhD Education, University of the Free State
Supervisor: Prof LC Jita

Thank you for submitting the revised project documents for ethics clearance by the Research Ethics Committee (REC), . In reviewing the documents, the comments and notes below are tabled for your consideration, attention and notification:

- **Proposal**

  - **Sampling & Administration Strategies, Pre-Service Teachers.** The REC took note that the primary *survey administration strategy* will be to collect data outside scheduled lecture times so as not to interfere with the University's normal functioning. However, should it be necessary to use a *survey administration strategy* during scheduled lecture times due written permission will be sought from the relevant lecturer and/or Head of Department; such permission letter/s will be submitted to the REC for notification before the onset of data collection activities.

- **Sampling & Administration Strategies, Pre-Service Teachers.** The REC took note that the survey questionnaire will be administered in a class group setup. Also, the REC took note that the researcher will duly inform all the potential participants that participation is entirely voluntary and they are free to withdraw at any point without any repercussions whatsoever. All the students in class who are not willing to participate in the survey and who might hold reservations about possible repercussions of their decision to not take part will be requested to merely stay with the group until the end of the survey completion; in this way, the identities of those who completed as well as those who chose not to participate in the survey can be duly protected.

- **Data Collection, Lecturer Questionnaire.** The REC took note that only Physical Science Methodology lecturers will be recruited to participate in the study. Also, the REC took note that these lecturers will initially only be invited to participate in the study (i.e. via E-mail or telephone). Only the lecturers who accept the invitation will then receive the Lecturer Questionnaire via E-mail; collection of the completed questionnaires will be hand-collected.

- **Questionnaire – Lecturers**

  - The REC took note that the lecturer questionnaire results will be reported in aggregate format to duly protect the identities of the participants. Also, the REC took note that in the event that the research results need to refer to a specific individual's results in any research output it will be done in a way that doesn't violate that individual's right to anonymity and/or confidentiality.

The Chairperson of the Research Ethics Committee, , reviewed the Memo outlining the project clarifications on February 27, 2017. **Final Approval** is granted to the study.

The proposed research project may now continue with the proviso that:

1) The researcher/s will conduct the study according to the procedures and methods indicated in the approved proposal, particularly in terms of any undertakings and/or assurances made regarding the confidentiality of the collected data.

2) The proposal will again be submitted to the Committee for prospective ethical clearance if there are any substantial changes from the approved proposal.

3) The researcher/s will act within the parameters of any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Strict adherence to the following South African legislation, where applicable, is especially important: Protection of Personal Information Act (Act 4 of 2013), Children's Act (Act 38 of 2005) and the National Health Act (Act 61 of 2003).

4) The current ethics approval expiry date for this project is **February 28, 2020**. No research activities may continue after the ethics approval expiry date. Submission of a duly completed Research Ethics Progress Report (available at: http://www. ac.za/Other/rninew/ResearchEthicsCommittees/Pages/default.aspx) will constitute an application for renewal of REC ethics approval.

Note:
The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants.

Yours sincerely,

Mr David Letloenyane

Clearance Nr: UFS-HSD2016/0627

University of the Free State

Department: School of Education Studies (Bloemfontein Campus)

letloenyanemd@ufs.ac.za

PERMISSION TO CONDUCT SURVEY FOR HIS PhD STUDY ENTITLED "SCIENCE TEACHER PREPARATION: AN ASSESSMENT OF THE OPPORTUNITIES TO LEARN AND THEIR EFFECTS ON PRE-SERVICE TEACHERS' COMPETENCE"

Dear Mr David Letloenyane

This is to confirm that you have been granted permission to conduct survey at campus for your PhD studies entitled "SCIENCE TEACHER PREPARATION: AN ASSESSMENT OF THE OPPORTUNITIES TO LEARN AND THEIR EFFECTS ON PRE-SERVICE TEACHERS' COMPETENCE"

The conditions of the permission are:

- The research will not interrupt any of the official activities at the ;
- You will supply us with the copy of your report;
- The cost of all related activities will be covered by yourself;
- Recruitment of participants is the sole responsibility of yourself;
- Voluntary nature of the potential participant's decision to consent to participate should be strictly observed;
- You should not disclose a potential participant's decision to participate or otherwise to any other party;

- Permission does not compel, in any sense, participation of staff members or students in your research.

DIRECTOR: INSTITUTIONAL RESEARCH AND QUALITY ENHANCEMENT

DR DM BALIA

20 SEPTEMBER 2016

Appendix 3: Letter to the universities

Room 220
Winkie Direko Building
University of the Free State
Bloemfontein

The registrar

REQUEST FOR PERMISSION TO CONDUCT RESEARCH

Dear Sir/Madam

I hereby request permission to conduct research in your faculty.

My name is Maleho Letloenyane, and I am presently studying for a doctoral degree with the University of the Free State. As part of my studies, I am required to conduct research on an aspect of interest with a view to making a contribution to our knowledge and understanding of the issues under study. The title of my research project is:

Science Teacher Preparation: An assessment of the opportunities to learn and their effects on pre-service teacher competence.

The purpose of this study is to determine the kinds of opportunities to learn that lead to competent novice physical science teachers in South Africa. I am particularly interested in measuring pre-service teachers' knowledge and beliefs as an indication of their competence towards the end of their training. I will then assess the opportunities to learn that their teacher education programmes offer and link them to their competence. The study will provide teacher education programmes with insights into the type of physical science teachers they are training through measures of competence and the effectiveness of each institutions programme according to the pre-service teachers' views. The study will also compare results from different institutions to determine what works best in terms of preparing physical science teachers. Your institution has been identified because it offers initial teacher education and there are final year pre-service physical science teacher in your institution.

The study will require final year pre-service physical science teachers to answer a questionnaire consisting of a knowledge test and a survey of their beliefs and the opportunities to learn that their programmes offer. The questionnaire for pre-service teachers will take about an hour to complete and will be administered during September and/or October in 2016. The teacher educators (lecturers) will also be required to fill in a survey which will take about 30 minutes to complete. The results from the lecturers' questionnaire will be compared with those from the pre-service teacher's questionnaire to establish similarities and differences in their views. The final results will be shared with various institutions and other interested parties.

Your institution may possibly suffer reputational damage as a result of this study. I therefore undertake to observe confidentiality, anonymity and to protect participants from physical and/or psychological harm. No names of the universities and/or persons shall be used in any reports of the research. The collected data will be protected by using codes and encryption to ensure anonymity and confidentiality. All participants will be informed that their participation is on voluntary basis and they may withdraw their participation at any time should they so wish.

If you need any further information and/or have suggestions, please contact me and/or my research supervisor Prof L.C Jita at

E-mail address / E-posadres jitalc@ufs.ac.za or 051 401 7522

I hope my request will reach your favourable consideration.

Yours sincerely

Maleho Letloenyane
Cell: 073 332 2752 (e-mail: letloenyanemd@ufs.ac.za)

Appendix 4: Cover letter for the questionnaire

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Room 220
Winkie Direko Building
University of the Free State

Pre-service physical science teacher

INVITATION TO PARTICIPATE IN A RESEARCH STUDY

Dear Sir/Madam

My name is Maleho Letloenyane and I am presently studying for a doctoral degree with the University of the Free State. As part of my studies, I am conducting a research study entitled:

Science Teacher Preparation: An assessment of the opportunities to learn and their effects on pre-service teacher competence.

The purpose of this study is to determine the kinds of opportunities to learn that lead to competent novice physical science teachers in South Africa. You have been identified as one of the final year physical science pre-service teacher and I would like you to participate in a survey to determine your level of competence with regards to teaching and learning physical science including your beliefs and the opportunities to learn that your programme offered you. The study will provide teacher education programmes with insights in to the type of physical science teachers they are training through measures of competence (knowledge and beliefs). The study will also compare results from different institutions to determine what works best in terms of preparing physical science teachers.

You are hereby requested to participate by answering a questionnaire consisting of a knowledge test and a survey of your beliefs and the opportunities to learn that your teacher education programme offers. The questionnaire will take about an hour to complete

I undertake to observe confidentiality and to protect all participants from physical and/or psychological harm. No names of the universities or persons shall be used in any report of the research. Your participation is entirely voluntary and you may withdraw at any time should you wish to do so.

The final results will be shared with various institutions and other interested parties.

If you need any further information and/or have suggestions, please contact me and/or my research supervisor Prof L.C Jita at

e-mail: jitalc@ufs.ac.za or 051 401 7522

or you can contact the chair person of the ethics committee

Education Ethics Committee, Office of the Dean: Education T: +27 (0)51 401 9683
email: RamohaiJ@ufs.ac.za

I hope my request will reach your favourable consideration.

Yours sincerely

Maleho Letloenyane
Tel: 051 401 7178 (e-mail: letloenyanemd@ufs.ac.za)