Examining the relationship between science teachers Beliefs and the PCK in stoichiometry in final year pre-service teachers

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By

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Plagiarism Declaration

I declare that this project is my own work and no part of it has been copied from another source (unless indicated as a quote). All phrases, sentences and paragraphs taken directly from other works have been cited and the reference recorded in full in the reference list.

Signature Date: 07 September 2017

Abstract

PCK is revered as the type of teacher professional knowledge required to transform subject matter into a form that is accessible by learners and when considered at a topic specific level, the knowledge is known as Topic Specific Pedagogical Content Knowledge (TSPCK). Research has ranked stoichiometry as one of the topic that is difficult to teach and learn due to its abstract nature. It has been reported that South African High School learners in particular, perform poorly in questions on this topic in the final national examination. Therefore, this may suggest that the science teachers are unable to teach stoichiometry in a manner that secures learners' conceptual understanding, therefore poor quality of TSPCK of teaching the topic. The main purpose of this study was to examine the relationship between pre-service teacher's TSPCK in stoichiometry and the beliefs they hold about teaching science. A mixed (MM) approach was used. The sample of pre-service teachers who were asked to participate in the research study was 24, these pre-service teachers have completed an intervention in their fourth year physical science methodology course on developing TSPCK in stoichiometry. Data comprised primarily of tools in TSPCK and science teacher beliefs completed at the end of the intervention, which happened to be the end of the course. Three key findings were made: (i) on completion of the intervention, pre-service teachers exhibited a functional good quality of TSPCK corresponding to 'Developing' according to the rubric used. (ii)The majority of pre-service teachers were found to hold transitional science teacher beliefs; and these were found to have an independent relationship with the quality of TSPCK as the professional teacher knowledge. The implication of this finding to the pre-service teachers is that pre-service teachers may hold teacher beliefs that are not necessarily corresponding to the quality of their professional knowledge of teaching a given topic (TSPCK). Secondly, pre-service science teacher's science teacher beliefs are more likely to change as they were found to be in a category called transitional, which is not strong in neither teacher nor learner centered oriented beliefs. Recommendations promote the development of TSPCK in stoichiometry and other core topics in physical science

Dedication

This study is dedicated to myself for all the sleepless nights and weekends I had to study, my parents Gloria and Tuwani Mashamba I thank you for everything you have done for me and most importantly to heavenly father. Thank you for your amazing love, blessings, support and wisdom for all the time.

Nga ndothe athikoni husina Mudzimu na lutendo, vha murangi na mukhunyeledzi wa lwendo lwanga.

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List of Acronyms

CK	Content Knowledge
CAPS	Curriculum and Assessment Policy Statement
DHET	Department of Higher Education and Training
DoE	Department of Education
DBE	Department of Basic Education
MM	Mixed Methods
PCK	Pedagogical Content Knowledge
TSPCK	Topic Specific Pedagogical Content Knowledge

Chapter 1: General introduction to the study

This chapter discusses an overview of the study and its purpose. It further discusses the research problem, the research questions in which the study seek to answer, the rationale behind the study. I conclude this chapter by giving an overview of the chapters in this study.

1.1 Introduction

In South African high schools, the teaching and learning of science has been a focus; this is due to the poor performance and results of the matric exams (DBE, 2012). (DBE,2012). Way back in the days even prior to Curriculum 2005 the learning of science was believed to be best learn through direct instruction from the teacher without learner's engagement in the classroom. Learners were seen as empty slates that only receive knowledge from the teacher or read textbooks. However, there have been concerns about learner's inadequate performance when it comes to stoichiometry of which it has been associated with teacher's lack of content knowledge, poor preparation and inexplicit teaching strategies to enhance learner's conceptual understanding (Mavhunga & Rollnick, 2013). Stoichiometry is a topic that is also included in matriculation examinations; it is included in the section of chemical equilibrium and chemical reaction (DBE, 2010). However, the national report (Departments of Basic Education & Higher Education and Training, 2011) on learner's performance on these questions is discouraging as it highlights the inability to solve stoichiometric problems and understanding of fundamental concepts.

Teachers are said to possess special knowledge for teaching known as Pedagogical content knowledge (PCK) which is the knowledge required to transform content knowledge for successful teaching. The concept of PCK has been discussed by Tamir (1988), Grossman, (1990), Magnusson, Krajcik and Bork (1999) since Shulman (1986) defined it as the transformations that a teacher makes of the subject matter to make it teachable.

PCK is seen as specific knowledge that a teacher has because of the experience they gained during their years in the teaching profession. It has been established that PCK is also topic specific, and therefore making it suitable as a theoretical construct to explore the teaching of the topic of Stoichiometry that is generally regarded as hard to teach and also difficult to learn (Fach, de Boer & Parchmann, 2007).

According to Mavhunga and Rollnick (2013) PCK at a topic level has to be conceptualized to reflect the topic specificity of the construct. Furthermore, since transformation of content knowledge is a benefit of PCK, at a topic specific level it is benefit derived from the re-conceptualized version of PCK that reflect topic specific nature. The conceptualized version of PCK was called Topic Specific PCK abbreviated (TSPCK). According to the authors, for each topic, the transformation of knowledge for teaching purpose is conceptualized within five content specific knowledge components. The advantages of this model, is that it allows "considerations topic by topic with less attention to the full spectrum of knowledge domains influencing PCK at a generic level" (Mavhunga & Rollnick, 2013). Hence we refer to this type of PCK as PCK within a topic, different from the generic type or PCK at a discipline level (Mavhunga & Rollnick, 2013, p. 116). Thus TSPCK is understood as the knowledge required of a teacher to transform the content of a specific topic (Mavhunga & Rollnick, 2013).

Stoichiometry is a topic taught in the South African High school curriculum from Grade 10 but more in detail in Grade 12. It is considered as the foundation of chemistry (Potgieter, Rogan & Howie, 2005). Therefore, it is crucial for students and teachers to have a good understanding of this topic and most importantly, it is expected that teachers possess strategies for transforming their content knowledge in this topic to enhance students' conceptual understanding. Hence, this study focuses specifically on the development of PCK in Stoichiometry and in revealing the science teacher's Beliefs that pre-service teachers hold as they complete an exposure to learning TSPCK. In this study I want to investigate the relationship between the quality of TSPCK and types of science teacher Beliefs held pre-service teachers as they leave and graduate out of the B Ed degree.

1.2 Purpose of the study

The purpose of this research study is to reveal the quality of chemistry pre-service teachers' TSPCK in stoichiometry and the science teacher Beliefs they hold as they graduate out of a PCK based programme as beginning teachers. Two major social driving forces are behind the study. The first is to contribute towards creating a pool of practicing science teachers in the South African education system that have the competence to pedagogically teach Stoichiometry for the understanding of learners. Such a competence is a benefit derived from having TSPCK in Stoichiometry. The second driving force is related to promoting the shared values that undergirds the nature of science as a discipline. One of these values is a teacher Belief system that promotes learner centeredness often delivered by enquiry in teaching science. While, the specific course in which TSPCK was learnt by pre-service teachers, does not have an explicit focus on science teacher Beliefs, it is important to determine whether such a focus should also be explicit. Although it has been reported by Mavhunga and Rollnick (2013) that teachers lack of content knowledge and method of teaching has an influence in their teaching. However, little is known about relationship between pre-service teacher's Beliefs and quality of PCK in stoichiometry. In addition to that, according to (Rollnick,Bennett, Rhemtula, Dharsey, & Ndlovu, 2008) Some teachers tend to spend more time teaching about the calculations rather than understanding the main content and concepts that learners has to acquire by the end of the lesson in stoichiometry. Therefore, this could be due to the kinds of Beliefs that science teachers held influence their teaching. It is very crucial that pre-service teachers possess both content knowledge and pedagogy to enable learner's conceptual understanding. Hence this study seeks to examine the quality of Topic Specific PCK as this could shed light into the kind of teaching approaches graduates from the PCK based course are likely to exhibit.

1.3 Problem statement

The literature on science education promotes learners-centred teacher Beliefs and ways of teaching (Luft & Roehring (2007). Whereas, another set of literature promote PCK in specific topic (TSPCK) as key teacher knowledge needed for effective teaching (Mavhunga & Rollnick, 2013). One can then reasonably understand that both these constructs, one talking to teacher knowledge and one talking to the affective domain are important. However, little is known about the relationship between the quality of TSPCK and the science teacher Beliefs held by pre-service teachers. While it may be desired that good quality of TSPCK would guarantee desirable teacher science Beliefs such as 'reformative Beliefs (Luft, 2009), it is yet to be understood whether the one has an influence on the other or vice versa. This is the gap not fully addressed in the science education literature.

In addition to that, teaching in our current school system employs teachers centred teaching strategies, where learners are marginalised (Mavhung,2016). It is important to establish the likely strategies to be used by the PCK prepared pre-service teachers based on their teacher science Beliefs and how these relate to the quality of PCK. This information is needed to inform the PCK based teacher preparation course, and determine the critical need for teaching pre-service teachers both PCK and teacher science Beliefs explicitly.

1.4 Research questions

This research study was thus guided by the following question:

Main Question:

What is the **relationship** between the quality of PCK in Stoichiometry and the science teacher beliefs that may be held by physical science pre-service teachers on completion of a TSPCK based intervention in the chemistry methodology course?

Sub-questions

- What is the quality of PCK in Stoichiometry of chemistry pre-service teachers at the end of an intervention in the chemistry methodology course?
- What kinds of science teacher beliefs are held by the pre-service teachers at the end of the intervention?
- What is the nature of the relationship between their quality of PCK in Stoichiometry and the science teacher beliefs they hold?

1.5 Rationale

The topic (stoichiometry) was selected on the basis that learners consistently fail to grasp the concept being taught to them and the problems arise due to the abstract nature of chemistry in which the teachers failed to address (Mitchell & Gunstone, 1984). According to Mavhunga and Rollnick (2013), pre-service teachers are likely to start their practice with weak PCK in core topics of science. Furthermore, in light of the prevalence of poorly prepared science teachers has (Potgieter, Rogan & Howie, 2005) there is a slim chance for beginning science teachers to hopefully learn sophisticated ways of teaching stoichiometry from mentor teacher in practice, as the latter currently do not register success. Thus there is a moral obligation for teacher education programme to address the development of teaching of science topics more explicitly. In addition, while the efforts dedicated to mitigating the learning of difficult science content in High schools is applauded, there is danger in producing teachers who have TSPCK in specific topics but delivers the evidence and the benefit derived from such knowledge in traditional ways of teaching, This would pose a threat to demising the explorative, learner-centred nature of science. Thus, the exploration, as in this study, of both TSPCK as the teacher knowledge element and the teacher science Beliefs as the affective element is very important.

1.6 An outline of research chapters

The following outlined chapters are used to report the study:

Chapter one mainly concerned with the research study, introducing the proposed study by stating and describing the problem of investigation, brief explanation of the purpose of the study and rationale was explained.

Chapter two focuses on the literature review related to the major themes of this study and the theoretical framework. The reviewed literature is about PCK, TSPCK, and science teacher's beliefs. The chapter ends with misconceptions and difficulties in teaching this topic.

Chapter three described on the methodology and design of the study. It further described the sample procedure of the study, how issues of ethical consideration were dealt with and research instruments that were used to gather the data.

Chapter four presented the data found about the quality of TSPCK at the end of the intervention

Chapter five present the data about science teacher's beliefs and the nature of relationship between TSPCK and science teacher's beliefs

Chapter six focus on the findings from the study by answering the research questions**,** implications of results and conclusion

1.7 Summary

This chapter has introduced the research topic, stating the problem and the motive behind this research and lastly it has explained the research questions that guide the study. Chapter 2 next presents the literature review of this study

Chapter Two- Literature review

Firstly this chapter provides a definition of PCK and then a review of the literature defining the construct of Topic Specific Pedagogical Content Knowledge (TSPCK) different from Pedagogical Content Knowledge (PCK) which is the theoretical framework of this study. Further discussion on Content Knowledge, defining stoichiometry, alternative conceptions about stoichiometry and conceptual teaching strategies in teaching stoichiometry is discussed and science teacher's Beliefs literature is reviewed.

2.1 Introduction

Poor performance in the subject of Physical science in matric examinations have been linked with teacher's poor content knowledge and ineffective teaching methods (Kriek & Grayson, 2009). According to Shulman (1986) having good content knowledge only and pedagogical strategies is not good enough in making knowledge accessible to the learners. Hence he identified Pedagogical Content Knowledge (PCK) as the most important knowledge. Ever since the origin of PCK 30 years ago, there is a growing belief that a good quality PCK can make a great impact in teaching and making knowledge accessible to all learners with different learning needs in order to transform their conceptual understanding in most classrooms (Park, Jan, Chen, & Jung, 2011). For this reason most research has been carried out on the components of PCK. In addition to that, there has been research proclaiming that the construct of PCK is topic specific this includes researchers like Mavhunga and Rollnick (2013); Van Driel,Verloop and De vos (1998) just to name a few. Previous studies have identified misconceptions and learning difficulties in stoichiometry and the concept of mole Malcolm and Mavhunga (2015); Dahsah and Coll (2007) ; Mitchell and Gunstone (1984) However, little is known about whether the quality of PCK in a topic is dependent on the science teacher Beliefs held by pre-service teachers. This is the gap not fully addressed in the science education literature. This has raised my interest investigation the pre-service teacher's knowledge and their Beliefs in teaching stoichiometry at the end of the intervention

2.2 What is Pedagogical Content Knowledge?

Before I dwell much one should ask, but what is this PCK and where does it base its ideology in education. Pedagogical Content Knowledge is a construct that arise from Shulman (1986, 1987) presentations about the discourse of teacher education. Shulman's work presented the ideology that teachers not only work with subject matter knowledge on its own capacity but, they work with subject matter knowledge, such that is it teachable. PCK is a special knowledge that teachers contain for teaching (Shulman, 1987).

Shulman (1986, 1987) noted that there are different kinds of classifications that make up teachers professional knowledge and thus, Pedagogical Content Knowledge is one of those classifications. PCK includes "the most powerful analogies, illustrations, examples, explanations, and demonstrations such that, the ways of representing and formulating the subject that makes it comprehensible for others" (Shulman, 1986, p.9). The key idea from Shulman is that teachers need to contain a firm PCK to be the exceptional teachers, they can be. The interesting fact is that Shulman presented this idea of PCK generically, meaning he did not specify for which subject area.

Shulman came to realize that, through his research and from that of his mentor, Schwab that the heart of what makes good teaching is what teachers know. From the above definitions I can say that it will be very challenging for a teacher to enhance learners understanding if he/she does not have a good content knowledge or conceptual understanding of the subject matter they teach, hence (PCK) is required so that learner's knowledge is transformed.

Moreover Shulman did not include the two types of knowledge which is curriculum knowledge and subject matter knowledge under the domain of PCK, although they are crucial in teaching. According to Shulman (1986) when we talk of subject matter knowledge this is the type of knowledge that includes the matter such as the amount of knowledge to be covered, as well as knowing what to teach in relation to the topic being taught or topic covered before in the previous grade by the learners.

According to Shulman (1986) PCK is not the same for all teachers, meaning that it is unique to each and every teacher. Further, he explained that PCK improves with experience; it can take years for a teacher to know what to teach and how to teach it. This implies that PCK is knowledge that beginning and pre-service teachers cannot easily learn from a textbook, or do as a short course. Van Driel, Verloop, and de Vos (1998), argue that novice teachers and experienced teachers who have not taught a particular topic before may have little or no PCK in that specific content area. On the other hand, "successful" teachers in a given content area, by which we mean those whose teaching in that particular content area promotes student learning, are likely to have well-developed PCK in that specific content area.

During the learning process in the classroom the teacher should try to understand the way students think in order to help them construct their understanding and create rich and meaningful interactions. In addition to that, the teachers should gain adequate PCK in order to be able scaffold, guide and transform students' knowledge throughout the lesson.

2.3 The difference between PCK and TSPCK

This idea of Topic Specific Content Knowledge (TSPCK) was influenced by the understanding that PCK has a topic specific nature as well as the transformation of concepts in the topic dealt with in (Mavhunga & Rollnick, 2013). TSPCK is a construct that exists as an entity within a topic and is separate from PCK in a discipline. TSPCK is the ability to transform subject matter knowledge (SMK) of any topic in from that will be accessible to students; which includes how it taught as well as the examples used (Mavhunga & Rollnick, 2013). TSPCK is different from PCK in the sense that if focuses on transformation of content concepts at the level of a topic, different from the generic PCK which maybe at a domain (chemistry) or subject level (science) (Veal & MaKinster, 1999). This means in order to teach a topic, it must first be pedagogically transformed. Similar, in learning TSPCK, there is a need to learn it topic by topic. In Mavhunga and Rollnick (2013), PCK at a topic level was conceptualized selectively from components of PCK that are content-specific, and reveal its topic specific nature. The construct was thus called TSPCK, and defined from a set of five content-specific components listed by Geddis and Wood (1997) as: (i) the knowledge about prior knowledge of learners; (ii) most important core concepts to be understood and their relations to prior concepts in the discipline (which they called curricular saliency); (iii) areas likely to pose potential difficulty for understanding by learners; (iv) representations specific to the topic; and (v) conceptual teaching strategies for the topic that take all of the above into consideration.

These components exclude components found in PCK models that are relevant at a discipline level, such as assessment. Thus, from the perspective of teaching PCK to pre-service teachers through the topic specific model, it is necessarily to remain alert to the fact that PCK developed in this manner is exclusively located in the topic given and cannot be claimed for more than that. This accounts for the use of the term TSPCK, not to be tautological but to distinguish the situationally of the acquired PCK.

2.4 Model of TSPCK as a theoretical framework in this study.

This model like other models originates from Shulman (1987), that PCK is a construct that emphasise that knowledge must be transformed in a way that it can be taught. Now, this model focuses the transformation of the knowledge within a topic-specific pedagogical content knowledge. Below is a Figure 2.1 that shows the model of Mavhunga (2012) it outlining different components of TSPCK.

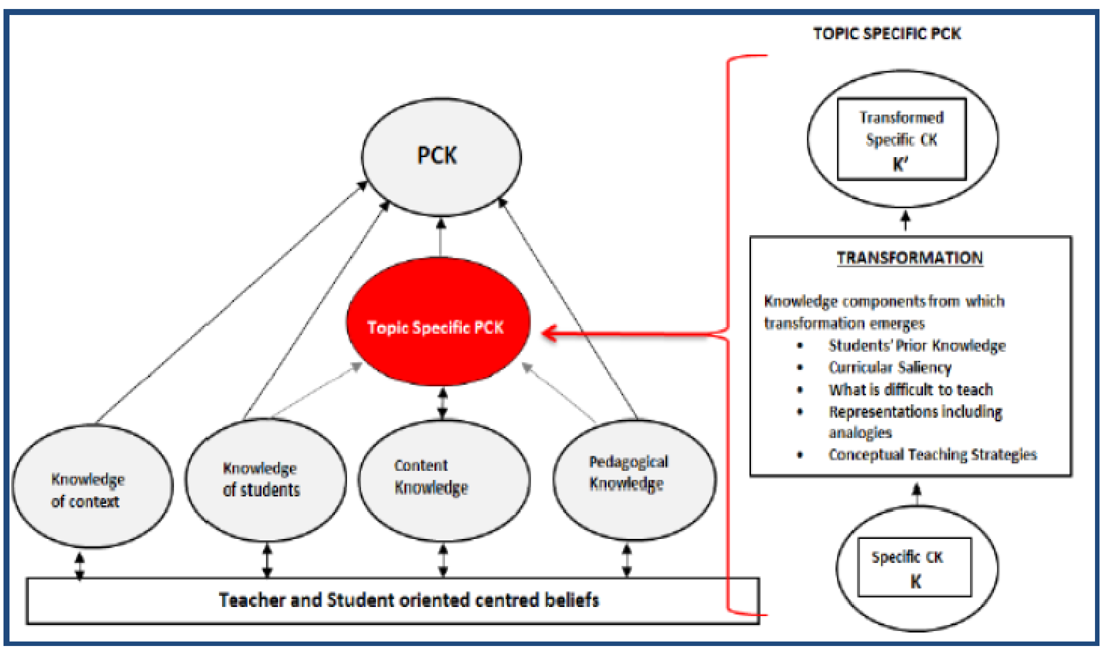

Figure 2.1: TSPCK knowledge domain model (Mavhunga, 2012)

This model Mavhunga (2012) consists of four knowledge domains, knowledge of context, knowledge of students, subject matter knowledge and pedagogical knowledge. While, this four knowledge bases might be common to content specific, the transformation of each topic specific

PCK is underpinned by five content specific components, namely students prior knowledge, curricular saliency, what is difficult to teach, representations including analogies and conceptual teaching strategies. Specifically this model focuses on transformation of specific SMK for it to be teachable to students.

Mavhunga and Rollnick (2013) identified that there are conceptions and misconception that students are likely to bring to class or are likely to develop during the teaching and learning process. In order for a teacher to know about the students prior knowledge or misconception in science or stoichiometry, it means that he/she has to engage learners in the learning process by taking them from what they know (everyday knowledge) to what they don’t know (not familiar with) by so doing that the development of level of the student grows to encompass that knowledge and the level of potential development shift or move ahead.

The second component of Mavhunga and Rollnick (2013) is curricular saliency which is regarded as the ability to analyse and organize a topic for purposes of planning for teaching. When we talk of curricular saliency this include the big ideas about a topic, subordinate concept and sequencing them. As a teacher one need to be able to re-arrange concepts or topic to be taught in the curriculum according to grade level of the learners and again know the reasons for choosing those topic and how they link to one another. By so doing that students understanding in a topic level will be enhance in a broader sense.

Terminology in science is difficult to teach but as a teacher it is vital that one knows and understand those concepts in order to enhance students understanding. Mavhunga and Rollnick (2013) discussed component about what is difficult to teach. As a constructivist science teacher one need to be able to identify the concepts that are difficult to teach and this includes conceptions and misconceptions within a topic. In addition to that a teacher has to suggest strategies on how to handle those difficult concepts. This means that a teacher needs to develop the teaching strategies that will work and apply in transforming learner’s content.

Furthermore, a teacher must develop knowledge of how to use representation in science, which includes things like models, diagrams and analogies that relate to learners everyday knowledge. Lastly is the knowledge on conceptual teaching strategies to be used when teaching. This component encompasses all the above catergories.it is believed that different learners learn in different ways, therefore a teacher need to be able use different teaching strategies to develop learners understanding of the correct science knowledge.

The special feature of Mavhunga and Rollnick (2013) model is that it is derived under the theoretical perspective that indicates that PCK can be measured. A teacher's topic specific PCK can be measured and be agreed upon, within a particular topic in science. This feature makes this model

The knowledge domain of the knowledge of context is the only aspect of knowledge that is not dependent on the topic. This emphasis indicates that a teacher's PCK in different science topics is influence by the same or common knowledge of context.

This model emphasise that the Topic Specific PCK has unique knowledge base for each topic being taught. For each topic, the transformation of knowledge for teaching purpose is conceptualized within five content specific components. The advantages of this model, is that it allows "considerations topic by topic with less attention to the full spectrum of knowledge domains influencing PCK at a generic level. Hence, we refer to this type of PCK as *PCK within a topic, different from the generic type or PCK at a discipline level" (Mavhunga & Rollnick, 2013, p. 116).*

This model is canonical, meaning with appropriate topic specific instruments, a teacher's TSPCK can be agreed upon. Mavhunga and Rollnick (2013) assert that PCK can be allocated within a topic. Their model emphasise a special knowledge required to transform the SMK of a topic, which is within knowledge concepts that are 'content-specific components'. Subject Matter Knowledge is a distinct knowledge domain within the conception of this model of TSPCK. The orientation of the SMK is present through the content specific components of a topic. Hence, this model is not generic across subjects, but topic specific within the science domain.

Mavhunga and Rollnick (2013) model, reflects practice within SMK topic transformation. The emphasis of this model is on the applicability of Topic Specific PCK research through practice in an intervention. Pre-service teachers TSPCK reflected that through adequate practice teachers can practice and elicit their TSPCK with a specific topic. This model was effectively used to assess TSPCK of the pre-service teacher such that some level of agreement is made to define the level of PCK within a specific topic (chemical equilibrium). Some extensive theoretical descriptions are constructed to assess the validity upon the level of TSPCK a teacher thus poses (Mavhunga & Rollnick, 2013).

The disadvantages of this model dwell from the fact that it can only compensate PCK within a single topic. That it clearly isolate that a teacher has many TSPCK for each topic, thus different topics incline a different PCK. The challenge is those teachers need to be taught and made aware of the complexities of each Topic Specific PCK. Any teachers PCK need not be used inter-changeably within topics in science discipline. Each topic requires teachers to be trained, such that they can portray and elicit their TSPCK topic by topic within a discipline.

This model, from evidence implies that there is a reciprocal relationship between Pedagogical Content Knowledge and pedagogical transformation (content-specific components). This model gives teachers and researchers the possibility to work with science topics individually with conceptual understanding of 'content-specific components' that each topic is transformed within for teaching purposes (Mavhunga & Rollnick, 2013). Thus, it implies that teachers need to learn the PCK of each topic in science and how the transformation of SMK/ content knowledge is done explicitly with five content specific components that composes content knowledge for teaching. TSPCK focus on the importance of content knowledge which a teacher can transform to produce PCK for that particular topic. Thus, a teacher needs to be conscious or knowledgeable of the transformation of content knowledge through five knowledge components of each topic to be taught in science.

As much as there has been many researches due to the expanding idea of PCK, many researchers came up with different models that focus on different aspects. Over the years, researchers have expanded the concept of PCK with various emphases. With extensive research, for example Mavhunga (2012) constructed a model that is narrowed to the practical research of teachers and pre-service teachers PCK topic by topic. However, each model of PCK should be regarded as vital depending on what the researcher's value in teacher education for pre-service teachers and for improving in-service teachers PCK.

2.5 The influence of beliefs on PCK

This model originates from the previous work of Cochran, DeRuiter and King (1993); Geddis and Wood (1997); Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008). Davidowitz and Rollnick (2011) model developed from research on what constitutes as teacher domains that inform the construct of PCK, such that the manifestations of teacher knowledge are the products. However, in this model the idea of teacher Beliefs was introduced as the fundamental establishment of any teacher's knowledge base, which has a two way relationship towards the domains of the teacher knowledge. Thus, this model developed from analysing what is observed in the classroom, to link with the existing theoretical knowledge bases that construct teachers PCK. These researchers argue that:

> Beliefs can be powerful mechanisms supporting the formation of constructive personal theories, which in turn inform practice. (Davidowitz & Rollnick, 2011, p. 357)

The focus of the model draws from practice, meaning the model is a result of observable evidence from a practicing tertiary teacher. Davidowitz and Rollnick (2011) model implies that PCK of an accomplished teacher needs to be captured and portrayed, so that new teachers can learn from accomplished teachers, on how they transform subject matter knowledge through their beliefs which influence how they teach.

The special feature of this model is that PCK of a teacher is different to the next teacher, because each teacher underlying Beliefs about teaching is influenced by the context and a topic. The authors assert that "Beliefs can be powerful mechanisms supporting the formation of constructive personal theories, which in turn inform practice" (Davidowitz & Rollnick, 2011, p.3). The teacher Beliefs are the base of teacher knowledge domains which influence the teachers PCK, hence through research these Beliefs can be observed through the classroom actions through how teacher teaches any topic in any way. The way in which a teacher transforms subject matter knowledge for teaching, is influenced by the pre-existing Beliefs about knowledge of subject matter, knowledge of students, general pedagogical knowledge and knowledge of context.

The manifestations of the teachers PCK indicated representations, curricular saliency, explanations, interactions with students and topic–specific instructional strategies. These manifestations are influenced by the teacher's particular subject matter knowledge, general knowledge of pedagogy, students and context.

The disadvantages of Davidowitz and Rollnick (2011) model eliminate knowledge of assessment as an essential manifestation of teacher knowledge that build up a teacher's PCK. However, in the earlier version of the model from Rollnick *et al,* (2008) is one of the integral observable evidence of a teacher's PCK. To some extend this model is topic-specific to organic chemistry, which the model is derived from a tertiary chemistry experienced teacher. Thus, chances are that the model might not be effective to elicit the same results in a research in different context and topic; however the same route can be used to elicit PCK of other experience chemistry teachers on a different topic.

Davidowitz and Rollnick (2011) model expands on the idea of the influence of teacher Beliefs and how that form the base of the teachers knowledge. This model implies that each expert teacher has specific Beliefs that influence how they teach each topic in chemistry, hence it results it the manifestations such as, the way they use representations, curricular saliency, explanations, how the teacher interacts with the students and the topic specific teaching strategies. These manifestations can be obtained through observing the expert teacher during planning of teaching and teaching. Because Beliefs about how students learnt and what they should learn within a specific topics is embedded within his/her Beliefs about what constitutes as big ideas and what are the student's difficulties on that topic. .

2.6 Defining Content knowledge

Before Shulman (1989) explained the meaning of Content knowledge (CK) he looked at different systems like Schwab's and Bloom. Schwab's (1987) outlines two types of knowledge: substantive "which is the concept that form the basis of the content", Schwab's (1987), in other words it deal with factual knowledge and how those kind of knowledge are grouped and organized together in such a way that they incorporate and those ideas are central and some are at peripheral. Syntactic "knowledge which is logical structure that comprises the discipline" Schwab (1987), to make it easier to understand I can put it as the type of knowledge that a teacher must have in order to establish the validity of something or a claim, for instant the types of examples that a teacher must use in order to make learner understand or believe what is being said or maybe to pursue them that a particular event did occur. According to Shulman (p8, 1987) content knowledge refers to the amount and organization of knowledge per se in the mind of the teacher. In other words one cannot teach what they do not know or understand. Hence a teacher needs to have good content knowledge, in order to deliver a good lesson and deepen student conceptual understanding. Shulman (1987) expressed the view that that content knowledge of a teacher is transformed by his/her PCK so that it can result into more intelligible students. In addition to that he stated that good PCK relies to some extent on good content knowledge.

Teachers must know and understand the subjects they teach. Teachers must also understand the nature of knowledge and inquiry in different fields this means that teachers who do not have these understandings can misrepresent those subjects to their students (Ball & MacDiarmid, 1990). Teachers' CK is crucial in enhancing students understanding of concept, because if the teacher's CK is poor then it means teachers will perpetuate those misconceptions to students.

According to Appleton (1995) teachers who have poor CK generally have low self-confidence for teaching science, and thus produce low quality lessons. Moreover, teachers with broad and deep understanding of subject specific knowledge tend to be aware of their learners conceptions and that helps them to be able to select models or different teaching strategies to enhance learners understanding. Borko (2004) argues that teachers must have rich and flexible knowledge of the subject that they teach, understanding the central facts and concepts of the discipline, how these ideas connect and process used to establish new knowledge and determine the validity of the claim. It is important for a teacher to have a good CK because when the teachers CK is weak it makes them look like they do not have experience in addition to that, it results in more teachers talk than engaging the learner in the learning process. It also affect the teacher negatively when it comes to teaching broader topics especially those that involve practical work. Hence content knowledge is crucial for good teaching

Many researchers' developed various models of PCK, one of the reviews by Jing-Jing (2014) critically discussed models in terms of their classifications of PCK, thus, each model portrayed Pedagogical Content Knowledge according to different emphasis on the model to distinguish it from the rest of the other models. Jing-Jing discussed the Shulman (1986), Tamir (1988), Grossman, (1990), Magnusson, Krajcik & Borko (1999), Andrew (2001) and Mark (1990), these are the main models that Jing-Jing (2014) critically reviewed, however other models such as, Geddis (1993) were reviewed to evaluate each models' nature, principle and trends of PCK components.

However, other models such as, Bishop and Denley (2007), Davidowitz and Rollnick (2011), Mavhunga (2012); Mavhunga and Rollnick (2013) are other models of PCK that has developed over research. Each model has a different emphasis hence; each model has developed from the other existing model, but branched to a different emphasis. Any component in each model resembles Shulmans (1986, 1987) domain of teacher knowledge.

2.7 Defining Stoichiometry

Stoichiometry is a topic taught in detail in grade 12 in South African high schools. It is considered as one of the foundation topics of chemistry. Therefore, it is crucial for students and teachers to have a good understanding of this topic and most importantly, it is expected that teachers possess strategies for transforming their content knowledge in this topic to enhance students' conceptual understanding. Stoichiometry is defined as the study of quantitative aspects of chemical formulas and reactions, these involves calculations based on chemical formulas and chemical equations (Silberberg, 2006, p. 90).

2.8 Learner alternative conceptions in stoichiometry

In order to transform learner's conceptual knowledge a teacher need to have an understanding of their conceptions about the topic at hand. Mitchell and Gunstone (1984) identified that learners have different conceptions about the topic of stoichiometry and also hold pre-concept about other topics that are crucial in understanding or solving problem is stoichiometry. Wrong conceptions about stoichiometry that are held by the learners make them to struggle or unable to work with stoichiometry calculations. According to Mitchell and Gunstone (1984) there are four different alternatives pre-concept that impact on learner's ability to understand the topic of stoichiometry. They have found that learners in South African context have problem in understanding the fact that atom are conserved during the process of chemical reaction. In addition to that, in their research Mitchell and Gunstone (1984) also discovered that learners have difficulties in differentiating the concepts such as atom, molecule and compound from each other; instead they used them interchangeably, which implies that leaners do not know the difference between this terms. Furthermore, it was also found that learners are able to balance a chemical equation. However, they are unable to solve problems related to stoichiometry. Furthermore, (Potgieter *et al*., 2005; Agung & Schwartz, 2007) found that another alternative conception that learners have is to distinguish between coefficient when working with chemical formulas. Therefore, this justifies the inability to solve stoichiometry chemical equations. When it comes to scientific terminology there seems to be more confusing to the learners. This is evident with the term 'amount of substance' and 'mass of substance', according to Dahsah and Coll (2007) the learners misunderstand the two terms and confuse them with one another. Another conception is that reactants need to be present in stoichiometry ratios represented by balanced chemical equations and lastly (Potgieter *et al*., 1996) have found that learners have difficulties in understanding the concept of limiting reagent.

2.9 Conceptual teaching strategies for teaching stoichiometry

Different learners have different learning abilities; therefore, it is important for a teacher to be able to use multiple teaching strategies in order to cater for different learning abilities. This means that whichever the teaching strategies the teacher decides to use; they should focus on transforming learner's knowledge. Most of the learners have been found to be relying on algorithmic method to solve stoichiometry problems and without having conceptual understanding of the concept (Dahsah & Coll, 2007). It is important that learners develop a conceptual understanding of the stoichiometry concept so that they would not experience troubles in understanding more advance concepts such as acid and base etc. So, as a teacher it is crucial that the teaching method focus more on the knowledge of students including alternative conceptions. The reason being that learners hold rooted misconceptions and conceptions as mentioned above about stoichiometry and they bring that to the classroom of which is inconsistent with science (Duit & Treagust, 2003).

A great method to transform learner's conceptual understanding is to teach content from a familiar or everyday situation, as the learners will be able to relate to it and make meaning from that. For example, reaction stoichiometry could be taught within the contexts of ore extraction and industrial processes such as the Haber process (Evans, Leinhardt, Karabinos, & Yaron, 2006). Another teaching strategy will be to develop proportional reasoning by allowing learners to logically solve given problems using their own understanding unlike algorithmic approach Schmidt (1997); (Schmidt & Jignéus,2003). According to (Frazer & Servant, 1986a) it is also important that teachers come up with strategies that can solve problems like making use of diagrams or different micro and macroscopic representation, use models, do experiment with the learners or if the environment does not allow that, they must demonstrate to the learners by so doing that it will cater for various learning abilities and can help learners in solving stoichiometry problems by enhancing their conceptual understanding. Another teaching strategy that was found to be effective in learning stoichiometry by (Georgiadou & Tsaparlis, 2000) was to do guide discovery learning, where learners are active participants in discovering their own knowledge, instead of waiting to receive information, like they are empty slate.

2.10 Challenges that pre-service teachers face

According to, Geddis ,Onslow, Beynon and Oesch (1993) teachers need to develop the awareness that teaching require the transformation of their subject matter knowledge. This means that when the teachers subject matter knowledge is developed, it also impacts positively to students understanding.

Although inexperienced teachers have incomplete and superficial levels of TSPCK and they tend to rely on unmodified subject matter knowledge (most often directly extracted from the text or curriculum materials) and may not have a coherent framework or perspective from which to present the information and also tends to make broad pedagogical decisions (such as whether or not to use cooperative learning) without assessing students' prior knowledge, ability levels, or learnings strategies. In addition to that studies of Cochran (1991) also indicates that novice teachers have major concerns about PCK, and they struggle with how to transform and represent the concepts and ideas in ways that makes sense to the specific students they are teaching.

Stoichiometry is an abstract concept and possesses challenges when teaching and learning it, the reason being that the processes are occurring on a scale that is difficult to visualize like the microscopic, the atom scale and molecules.

2.11 Science Teachers' Beliefs

According to (Luft & Roehrig, 2007, p47) Beliefs are considered to be propositions that individual think are true. It is believed that teacher's Beliefs have huge impact when it comes to teaching and learning. This means that teachers are not empty slate which just transmit information to the learners but have personal construct about each and every topic they teach. Beginning teachers teach based on their everyday experience of the outside world in order to mould topic teaching and learning (Luft & Roehrig ,2007). This means that they bring their own understanding and Beliefs of teaching in the classroom of which influence their decision making.

Luft and Roehrig (2007) report that there is a growing body of research on beliefs in science education, where beliefs linked to the use of enquiry, national reforms, or constructivist practices in the classroom are being studied. However, Millwood and Sandoval (2006) believe that too little is known of students' Beliefs about the epistemological aspects of school science and how these Beliefs relate to their Beliefs about professional science. Luft and Roehrig (2007) argue that understanding the Beliefs of science teachers is essential if teacher education programmes are to support the ongoing development of science teachers. Moreover, Hashweh (1996) asserts that despite numerous changes that have happened in the curricula of many countries, science teachers, particularly in developing countries, have remained stuck in traditional practices, and their Beliefs have not been affected by those curricular shifts. He argues that many studies have concluded that teachers are positivist in their views of scientific knowledge. These teachers believe that reality is stable and can be observed and described without interfering with the phenomena being studied. Hashweh argues teachers do despite the fact that positivism contradicts the constructivist view of learning and knowledge advocated by recent educational reforms. Hashweh goes on to say that observations of classroom teaching show that lecturing and the neglect of students' ideas are the prominent methods of teaching, in spite of their contradiction of a constructivist basis of learning and teaching that focuses on the importance of students' prior ideas, and the active construction of knowledge by the learner.

Beliefs can be categorised as traditional where students learn facts and concepts by absorbing the concept of their teachers explanation without them being engaged in the learning process or constructivist Belief which suggest that learners should construct their own knowledge which influence interaction with peers (Luft & Roehrig,2007). According to Simmons et al (1999) spoke about teacher centred teaching style which can be seen as traditional, where teacher is seen as the mediator of knowledge to students. Secondly is conceptual teaching style where we find that the main content that learners need to know is integrated with the processes instead of focusing more on teachers or students at the centre and lastly there's students-centred teaching style which encourage students interaction, meaning that students are responsible for their own learning and the teacher is seen as the facilitator unlike in teacher centred learning, so this seen as the constructive Belief point of view.

Science teacher's Beliefs play an important role in the classroom as they help in predicting teacher's decision and also influence the teacher's behaviour in certain situations (Luft & Roehrig,2007). In addition to that, Luft and Roehrig (2007) argued people have different Beliefs and some of this Beliefs are strongly held than others which resulting in "core" which are Beliefs that are connected and coherent with one another, in simple terms it will be very difficult for one to change the core Beliefs of an individual as they are embedded within and "peripheral" Beliefs which means that unlike the core beliefs they are not connected to others. Furthermore as people or rather as science teachers we don't think and see things the same way, this also applies to Belief which means that Individuals may have competing Belief sets about the same topic

For this study I will be looking specifically on pre-service science teachers Beliefs which according to Simmons et al. (1999) pre-service science teachers may hold many competing Beliefs sets which change or "wobble". From their study they have found that most of their participants of which are beginning science teachers they "wobbled" between more teacher-centred and more student-centred Beliefs about what students should be doing in the classroom. The reason the pre-service science teacher's Beliefs "wobble" s because their Beliefs as novice teachers they are not yet connected, not well developed and they are unstable unlike experienced or practicing teachers. Similarly, Luft and Roehrig (2007) found that science teachers within the first three years of their teaching they held unstable Beliefs about student-centred versus teacher-centred learning.

Teacher's knowledge of teaching a topic is more important in transforming learners understanding particularly TSPCK. This means that as a teacher one needs to have good content knowledge in order to deliver a good lesson and deepen student conceptual understanding. According to Mavhunga and Rollnick (2013), pre-service teachers start their practice with weak

PCK in the South African context; In particular, there is a prevalence of poorly prepared science teachers. The above statement basically means that due to lack of teaching experience the pre-service science teachers display teacher centred teaching strategy rather than learner centred teaching practice which is inquiry base.

According to Luft and Roehrig (2007) indicated that induction years is a key way to influence practice towards more student-centred orientations, hence this research will focus on pre-service teachers so that it can be able to shape or shift their Beliefs and practice at an early age by special type of knowledge known as TSPCK.

2.12 Summary

Discussion related to the literature were provided with regards to model of PCK and TSPCK which is the theoretical framework that guide this study, conceptions and teaching strategies to teach stoichiometry were explained. The next chapter present the research methodology.

Chapter Three- Research methodology

This chapter discusses research methodologies, sampling procedure, the process on the research intervention, data collection instruments used in the study, data analysis to achieve the aims of the study and their relevance to the study. Finally provide the issues of validity, reliability and how ethics were dealt with.

3.1 Introduction

There are three components to this research study. The first is the determination of the quality of Topic Specific PCK, while the second the component is to identify the kinds of Beliefs held by pre-service science teachers at the end of intervention. Lastly, to explore the nature of relationship that exists between two constructs.

3.2 Research Design

In order to address the research problem and answer the research questions to the study, a mixed method (MM) research method was employed. According to Tashakkori and Creswell (2007) mixed method study means doing research that involves analysing and collecting data by integrating both qualitative and quantitative approach in one study. This study fall under the pragmatic paradigm this according to (Onwuegbuzi & Johnson, 2006) is defined as the approach that draw from both the positivist and constructivist and uses quantitative and qualitative approach.

The reason for selecting a mixed method approach is that by combining qualitative and quantitative approach it will provide a better understanding of the nature of the relationship between a tacit construct such as TSPCK and an affective construct such as science teacher Beliefs. The benefit of this research approach is that it will give the in-depth understanding of the pre-service teacher's development of their TSPCK. In addition to that, it will help in providing more evidence than using one method of which could be insufficient by itself (Tashakkori & Creswell,2007).

According to Creswell (2012) qualitative approach permits an in-depth exploration of a few individuals. The TSPCK and science teacher Beliefs tools serve as both qualitative and quantitative tools. In my study both the qualitative and the quantitative have equal weighting as initial responses were collected from the tool in the form of qualitative thick descriptions which were later converted for analysis through quantitative means (explained in detail later). Furthermore, some data were collected in independent qualitative form like interviews and used to triangulate other data (explained later). So both methods were given equal weighting.

3.3 Sample of the Study-Case study

The sample of pre-service teachers who were asked to participate in the research study was 24 physical science (chemistry) methodology class. The study was looking at the data that was collected but not analyzed a year before my study. The set of pre-service teachers were exposed to six weeks' intervention in stoichiometry.

According to Punch (2009, p. 119) a case study is comprising of individuals or a small group studied in detail using whatever methods and data seem appropriate. A case study is one of the several methods to carry out research study by seeking to understand social context of human beings by interpreting actions as an individual group, community or a single event (McMillan & Schumacher, 2010). The advantage using pre-service science teachers as a case study is that it gives detailed and clear information regarding the event or setting under investigation (Merriam, 1998). This case study approach enables directed full explorations of interactions (Mavhunga & Rollnick, 2013) of the issues to be investigated. This will be an appropriate strategy to use in this study as it will give me the opportunity of focusing on an in-depth exploration (Creswell, 2012) of the participant pre-service teachers' Topic Specific PCK.

The sample of 24 pre-service teachers in their final year of study towards a B Ed degree, were majoring in physical science. This degree would enable them to teach in High schools where the topic of Stoichiometry is taught. The study was located in the methodology class of physical science IV, the pre-service teachers were exposed to an intervention that explicitly discusses TSPCK in stoichiometry and the competence of how to transform content knowledge in this topic. For this study, the entire sample was considered for both determining the quality of TSPCK and science teacher Beliefs. This sample included pre-service teachers from various social backgrounds and composed of both genders from various population groups. The sample was dominantly comprising of female pre-service teachers and only 11 male pre-service teachers who are male (see the table below 3.1).

Table 3.1: The gender profile of the pre-service teachers in the sample.

pre-service teachers	Gender
Jane	Female
Gift	Male
Newi	Female
Mpho	Female
ori	Female
Kate	Female
Abie	Male
Muli	Male
Vule	Male
Kane	Male
Xolo	Female
Amy	Female
Athi	Male
Funi	Male
Game	Male
Zaza	Female
Newi	Male
Rabe	Female
Gale	Female
Josh	Male
Didi	Male
Taki	Female
Aggy	Female
Kim	Female

The participants are now graduates of the Wits school of education. Some are now practicing as beginning science teachers whereas others are furthering their studies. The main reason for choosing this group of students is because my study targets the prospective teachers in training who have been exposed to a PCK based course.

3.4 The treatment

I did not deliver the treatment in person, but established the content of the treatment from consultation with the class notes, lecturer plan and personal conversations from the lecturer who conducted it. It must be noted that, while this treatment is described as a treatment from the perspective of this study, it is actually the normal content of the course. The description of the course is public knowledge published in detail as course outline and made available through the Wits University archives. I now provide the content of the treatment as based from my research.

The pre-service teachers were exposed to 6 weeks intervention program of which lasted for 12 sessions, where a session was an hour long. The purpose of the intervention was to develop pre-service teachers understanding of stoichiometry from the TSPCK perspective and develop the competence to transform content knowledge of stoichiometry (Mavhunga 2016). In the intervention the components of TSPCK were taught one at a time in a sequence given in Table 3.2 below.

Table 3.2: Description of the intervention of stoichiometry

During first session pre TSPCK tool was administered for data collection		
Weeks	**Component**	**Intervention**
week 1	Learners prior knowledge	The first lesson was on the alternative conceptions and misconceptions in teaching stoichiometry. Then they had to discuss the method in which they can use to correct learners misconceptions
week 2	Curricular saliency	The discussion was on the topic that require the pre-service teacher understanding of stoichiometry of which then they had to identify main big ideas to be taught and the manner in which it should be taught and lastly to show how they all relate to one another
week 3	What is difficult to teach	During this lesson they had to use their knowledge of stoichiometry in order to identify topic that are difficult to teach. This was achieved by using or relating it to learners' conceptions and misconception about the topic.
week 4	Knowledge of representations	The lesson was centred on comparing different types of representation that are used or can be used to teach stoichiometry and also to see if the pre-service teachers can choose the best model for teaching
week 5	Conceptual Teaching strategies	The lesson was outlining different teaching method to teach stoichiometry. And to see if the teachers can incorporate various teaching strategies to enhance learners conceptual understanding.
week 6		During the last session the pre-service teachers were taught about Content Representations (CoRe)
last session post TSPCK tool was administered for data collection		

3.5 Collection of data

I have access the archives of the course to retrieve data that was submitted in 2015, as sets of test conducted at the end of intervention. The pre-service science teachers were asked to complete questionnaire before the intervention and the other set at the end of the intervention. Only the TSPCK questionnaire was administered as pre and post task, but for the purpose of this study the focus is on the batch of tests conducted at the end of the intervention, as the purpose of my study was less on the impact of the intervention but a snapshot of the status at the point of completion.

Particularly, completed tools related to TSPCK in Stoichiometry and science teacher Beliefs. In order for me to get an in-depth understanding of teacher's knowledge and their Beliefs, I conducted recall face to face interviews with 1 of the participants at Wits school of education. The candidate was registered for BSc Honors (Science Education) at the institution hence the participant was met. However, the other participants were not available to participate in the research interview.

According to Opie (2004) interview is a verbal conversation between the interviewer and the interviewee with the purpose of collecting information for the purpose of the research. This method was selected because Opie (2004) argues that respondents are encouraged to develop their own ideas, feelings, insights, expectations or attitudes when interviewed. In other words the participants are able to say what they think with great richness and spontaneity. In order to get more information I have used semi-structured interview questions. The aim of the interview is to expand and clarify provided responses to confirm or refute emerging analysis.

The process for conducting the interview process consisted of a meeting which took between 20 to 30 minutes and included the TSPCK and teachers Beliefs responses along with a series of additional probing questions. An appointment was made with the participants for the meeting. During the interview, the audiotape was used and the information was transcribed during the data analysis. Below is a list of probing question asked during the interview. For full interview schedule (see appendix 11)

Interview questions:

1. What is your understanding about Topic Specific Pedagogical Content Knowledge?
2. How is this understanding different or similar to that you held in your pre-service teacher programme?

3.6 Description of research instruments

Two questionnaires were used in this study – one for measuring TSPCK, the other for science teacher's Beliefs. Both questionnaires can be found in (Appendices 7 and 9).

3.6.1 Topic Specific PCK (stoichiometry) tool

The first instrument that was used for this study was a questionnaire testing the pre-service teachers' TSPCK. The questionnaire was set up to access information on how pre-service teachers in their final year of study think and reason about the way they teach stoichiometry. This instrument is based on Mavhunga and Rollnick (2013) model and developed and validated by Malcolm (2014). The questionnaire consists of five components see Table 3.3 below illustrates the type of items that were designed for each of the components in the tool. The rubric used for scoring the quality of the respondents' TSPCK from this instrument is included in Appendix 8. The scoring process is outlined in data analysis.

Table 3.3: Types of questions designed for the components of TSPCK in stoichiometry

Component	Type of Question
Learner prior knowledge	Respondents were asked to comment on a teaching situation involving misconceptions and another involving prior knowledge and ask the pre-service teacher to choose the best response and give valid reason for their choice
Curricular saliency	They were asked to identify big ideas then show the sequence in which they will teach them, show how all those big ideas link to one another and lastly they were asked to identify the topics that require understanding prior teaching stoichiometry
What makes the topic difficult to understand	Pre-service teachers were given concepts and were asked to identify with reason the concepts that are difficult to teach to the learners
Representations or models	Were asked to comment on content representation/analogy of stoichiometry, explain what they like and dislike about each representation. In addition they were asked to choose one representation and explain how they will used in a classroom setting
Conceptual teaching strategies	the teachers had to choose the best analogy that they find useful in classroom setting in order to enhance learners conceptual understanding

The TSPCK instrument measures the pre-service teacher's knowledge in stoichiometry. It has distinguishable headings of five TSPCK components at the top of new page.

The above mentioned components have one or more questions that are testing teacher's knowledge of the topic of stoichiometry. In addition to that, participants were provided with space to write detailed responses.

3.6.2 Science teacher Beliefs tool

The second instrument was Beliefs tool which aimed to measure the pre-service teacher's kinds of Beliefs in science. It is a mini task composed of 7 questions that were developed and validated by (Luft & Roehrig,2007). Beliefs tool was administered to the pre-service teacher's end of the intervention. It was set to examine the kinds of Beliefs that are held by the pre-service teachers at the end of the intervention, regarding their effective stoichiometry teaching and learning.

Table 3.4: Questions used for teacher Beliefs tool

Questions format	Areas addressed
1. How do you maximize student learning in your classroom?	This question was more focused on the learning environment of the learners.
2. How do you describe your role as a teacher?	Focused on the learners knowledge
3. How do you know when your students understand?	Focused on transforming knowledge
4. How do you decide what to teach and what not to teach?	Learners and content knowledge
5. How do you decide when to move on to a new topic in your classroom?	Method used to assess learners knowledge
6. How do students learn science best?	Learning strategies
7. How do you know when learning is occurring in your classroom?	

Just like the TSPCK tool the participants were provided with space for their detailed responses. The types of questions that were asked were open ended and were clearly stated and straightforward to the pre-service teacher in order to explore their Beliefs.

Both questionnaires had cover page that was used to capture the details and demography of pre-service teachers participating in the study. To keep their information private, the cover page of the questionnaires was used to give each one of the participants a unique code that were written onto each page of the tool.

3.7 Data analysis

According to Creswell (2003, p.190) when we talk of the process of data analysis it means making sense from the provided text and image data. In addition to that, it includes the writing and asking questions about the study as the data being collected.

3.7.1 TSPCK stoichiometry tool

All questionnaires were given codes then scanned and saved in the drop box where only me and my supervisors could access them electronically. Both questionnaires were analysed qualitatively and quantitatively.

In order to assess and rate the participant's knowledge on the five categories of TSPCK responses a rubric adapted from Mavhunga and Rollnick (2011) was used. As can be seen in the Figure 3.1 below, the TSPCK rubric show the criteria that must be meet as well as the rating scheme. Furthermore, no answer was awarded a zero which means that even a question with no response was assigned a '1', the lowest score; a question with responses across more than one category can be scored by looking at a combination of the two answers. The rubric was used as the guideline to award the level in which the pre-service teacher falls in as well as classifying them as having either Limited, Basic, Developing and Exemplary Topic Specific PCK. The description in each criterion was used to justify an award of a specific rating to the pre-service teacher. The rating of all the pre-service teachers' responses to the post tool was indicated by a mark in the relevant column of each row. Each and every row shows a criterion that sowed progression of TSPCK from basic to exemplary. The rubric consisted of 5 column and rows. The first column contained the five components of TSPCK and column 2 up to 5 contains the ratings in brackets of that criteria. Each category was graded using four-point scale which range from 1 which is (limited) to the last one which is 4 (exemplary) and the total scores for the whole instrument was 20 points. An excerpt from the rubric is shown below in figure 1. The full rubric can be found in (Appendix 8)

	Limited(1)	(2) Basic	(3) Developing	Exemplary (4)
Learner Prior Knowledge	• No identification/No acknowledgement/No consideration of student prior knowledge or misconceptions • No attempt to address the misconception.	• Identifies misconception or prior knowledge • Provides standardized definition as a means to counteract the misconception • No evidence of drawing on other TSPCK components.	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Expands and re-phrase explanation using one other component of TSPCK interactively.	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Expands and re-phrases explanation correctly • Confronts misconceptions/confirms accurate understanding drawing on two or more other component of TSPCK interactively.

Figure 3.1: An excerpt from the TSPCK marking rubric

After assessing each questionnaire, the raw scores were then entered into the Rasch statistical model. Rasch statistical model is a software that is used to measure an individual's performance in relation to the items and the item difficulty. The Rasch program was used because it changes the ordinal data it into linear measurements.

3.7.2 Science teacher's Beliefs tool

The science teacher's Beliefs was analysed using the Beliefs map rubric by Luft & Ruehrig (2007). The Beliefs map consists of 5 different categories and they all differ with regards to the degree of engagement with the questions. The categories in the maps were labelled as follow: those that are teacher cantered responses were classified as either traditional or instructive Beliefs and responsive and reformed based were classified as students cantered beliefs in addition to that the (Luft and Roehrig, 2007) classified the responses that shows primarily behaviourist and affective students attributes as transitional beliefs. The Beliefs maps were scaled from 1 to 5 in order to show the pre-service teachers categories as whether they are teacher or students centred Beliefs. Below is an example of Beliefs map. The remaining maps can be found in (Appendix 10)

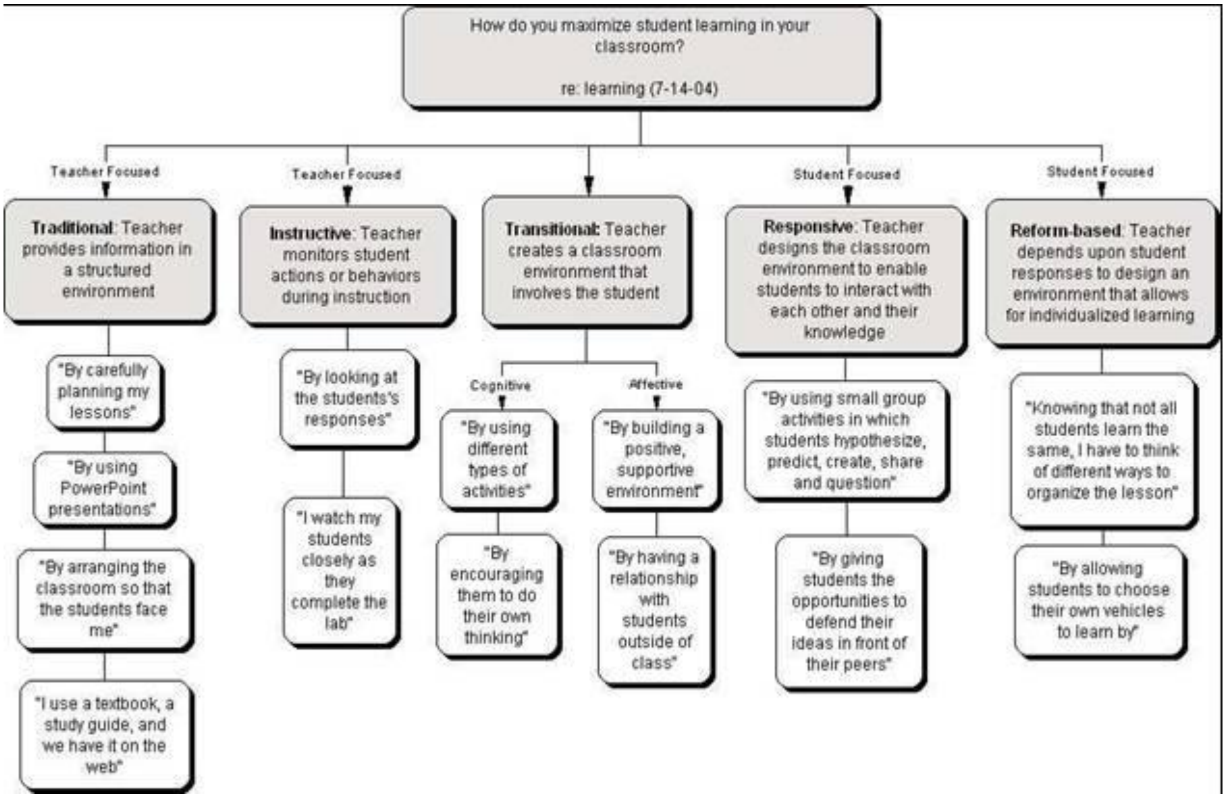

Figure 3.2: Beliefs Map of Question 1

With regards to the traditional Beliefs it is more focused in the ancient days method of teaching where the teacher is regarded as the knower or rather the source of knowledge or information and should transmit it to their learners, learners are seen as passive participants. Secondly, instructive belief view science as rule or fact, It is more focused on the teacher, as the class instructor who maintain the students focus in order to avoid class disruption. Thirdly, it is transitional Belief which represents science as consistent body of knowledge that is connected and has objectives to be achieved. This Belief is more focused on the teacher/student relationship, instead of being one sided. The teachers have a good rapport with his or her learners and do what they like or enjoy to in science and is seen as the guidance or facilitator in their development and understanding skills. Fourthly, responsive Belief which supports learner's collaboration, giving positive reinforcement feedback or knowledge in order to enhance learners conceptual understanding. Learners are active participants and are involved in making decision of their own learning. Lastly is reformed based belief which focuses on mediating student knowledge or interactions. The role of the teacher here is to provide students with experiences in science, which allows the teacher to understand their knowledge and how they are making sense of science. The teacher's instruction needs to be modified accordingly so that students understand key concepts in science. Luft and Roehrig (2007) noted that to understand, or elicit the Beliefs of teachers, it is important to make beliefs "visible". Fang (1996) has noted the shortcomings of written self-report responses. Teachers tend to reflect, in their answers, what should be done rather than what is actually done in their teacher practice.

3.8 Validity and reliability of the tools

As defined by Bush (2002) validity can be seen as the extent to which a measurement, or 'score', measures what it was intended to measure. For this study the terms validity and reliability are used to determine the quality of the two tools that were used. The designed tools will be useful only if they measure what they are intended to measure and if the data obtained from them is meaningful (Creswell, 2012). Reliability is closely related to validity and refers to the extent that consistency of results is obtained – would similar results be obtained with another, comparable sample population (Neuman, 2000).

3.8.1 Qualitative Reliability

The responses to both assessment tools were analyzed qualitatively, more in line with the interpretivist research tradition. Using this methodology entails looking for meaning in the responses and relating it to the construct being tested (Neuman, 2000).The use of the model of Mavhunga & Rollnick, (2012), that had been tested and validated with other topics, like electric circuit and particulate nature of matter, was the starting point of validity.

To validate the assessment of the TSPCK and Science teacher's Beliefs answers to the questionnaires, three other researchers from the same group scored the same questionnaires. Before the marking commenced all three of us sat together and agreed on the correct answers to the questions. We all reached a common understanding of coding and analyzing using the designed rubric and beliefs maps. After agreeing on the rules and procedures for scoring, each researcher went ahead and scored their individual two questionnaires.

When scoring the questionnaires there were some differences when it comes to marks allocation by the other researchers and that was resolved by comparing their scores with mine and then took the average in order to give the student mark for that question.

In order to increase the reliability of the tools qualitatively, it was crucial to look for evidence in both the TSPCK and the Beliefs questionnaires for the type of knowledge transformation that pre-service teachers require for demonstrating TSPCK in stoichiometry. Furthermore, the results or rather scores obtained from the Beliefs and TSPCK tool were compared in order to see if there's any relationship that existed between them.

3.8.2 Quantitative validation

For the quantitative aspect of this study, the raw scores of the TSPCK tool were analyzed using the Rasch model, which uses Winsteps software. The advantage of this model is that it converts the raw data into linear scale. As compare, to other statistical models which measure average numerical data and which background the range of responses, Rasch focuses on the item and person score, thus measuring the validity and reliability of a single parameter. According to (Bond and Fox, 2001) this particular scale is called the normalized Rasch and it further allow the ranking of a person ability based on item difficulty. Rasch model was selected because it measures the extent to which each single construct is being measured. In this case it is important to know whether the construct of TSPCK tool is what is actually being measured.

The Rasch software generates a data matrix based on item difficulty and person ability. The higher the level of validity of the data, the more coherently these two constructs work together. In other words, more difficult items have fewer correct answers and easier items have the most correct answers and 'persons' getting the more difficult items correct are also getting the easier items correct. In order to measure this coherence, two indices of fit, namely, *Infit* and *Outfit*, are calculated. Linacre (2012) describes the fit statistic as the difference between a person's observed score and the predicted score, statistically calculated, based on the person's ability. The *Infit* indices are a measure of the discrepancies between a person's expected performance and observed performance. The *Outfit* index reflects items that are quite distant from a person's ability level and therefore not expected to be achieved (Boone & Rogan, 2005, p. 34). A range between -2 and +2 is seen as an empirical argument for validity (Bond & Fox, 2001).

3.9 Ethical considerations

The data used in this study was collected in 2015.However, the study involved voluntary participants from the Wits school of education in their final year of study and were all above legal age, hence no consent forms were issued to parents. An information letter was handed to the pre-service teachers to inform them about the study. Letters were written to the head of school, head of science division and course coordinators physical science methodology class EDUC 4143 asking for permission. The consent forms for the pre-service teachers were also handed out before they were exposed to the intervention. It was made clear in the consent forms to all pre-service teachers that participation is voluntary and anybody can terminate her/his participation at any time. I had been granted permission to use the data for my research project and uphold their ethical requirements, and my protocol number is 2016ECE023M, refer to Appendix 3.

It is important to maintain the confidentiality and anonymity of the participants, and I have accomplished this by calling the participants by the codes given to each and every one of them. This is the protection of informants from the general reading public, though it will not be possible to ensure the anonymity between the pre-service teachers or to protect the participants' confidences from one another in the setting whose private information might enable them to identify them. They attend in the same class or lecture venue, they know each other and they gave consent so I think that might affect the anonymity.

3.10 Summary

In this chapter I have described my research design and methodology, I have provided detailed descriptions of my sample, research analysis, and how I obtained the data. The next chapter four provides more detail on the findings of the study.

Chapter Four- The quality of Pre-service teachers' TSPCK as they leave the program

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In this chapter, I will present the findings from my mixed methods analysis of the Topic Specific PCK in stoichiometry. The data presented are responses from a set of post-intervention TSPCK tool at the end of intervention. I briefly describe the analysis and present findings on TSPCK .Furthermore, show validity and reliability of the findings through. I close by summarizing the findings in relation to the research question investigated

4.1 Introduction

According to Creswell (2003) the process of data analysis is regarded as "making sense out of text and image data." (p. 190). Data analysis is a process that includes an ongoing and continual reflection about the nature of the data being collected. It also involves writing and asking analytic questions about the study as the data are collected. It is an open-ended process which requires asking questions and working to develop an analysis from the information supplied by the research participants. As part of the process generative themes and categories emerge from information provided by participants, and it needs to be contextually tailored to the methodology chosen by the researcher (Creswell, 2003).

In this Chapter, I provide the analysis of data collected about the impact on an intervention that targeted the development of TSPCK in the topic of stoichiometry. In order to analyze the data both the qualitative and quantitative research methods were employed. The simultaneous use of the two research methods laid a foundation to begin to answer the first research questions of this study, which was: What is the quality of PCK in Stoichiometry of chemistry pre-service teachers at the end of an intervention in the chemistry methodology course.

In order to determine the quality of pre-service teachers' TSPCK following an explicit intervention targeting the development of the competence to pedagogically transform content knowledge, the completed post-intervention TSPCK tool were scored using a validated TSPCK rubric (Mavhunga and Rollnick,2013). The post TSPCK scores were measured as I needed to know the quality of TSPCK at the end of the intervention and compare it later (see Chapter 6) to the patterns of the underlying science teacher beliefs.

I analyzed the responses in light of their engagement with the question and then graded each teacher's responses that matched a certain criterion according to the TSPCK they presented (see rubric in Appendix 8).

For establishing reliability of the generated scores I scored the completed tools with peers, one doctoral student who developed the tool in a previous separate study and one physical science teacher who has been teaching stoichiometry over 5 years and whose research is also on TSPCK. We first all reached a common understanding of coding rules and analyzing using the rubric. The concept of reliability is about the extent to which a procedure produces similar results under the same conditions Bush (2002). There was mostly agreement across the raters with very few cases of disagreement which were then resolved by discussion and pointing to evidence. For example, Table 4.1 below displays the scoring of the responses from three participants

Table 4.1: Results of the validation of TSPCK scores

	ASSESSOR A		ASSESSOR B		ASSESSOR C	
	Aggy	Aggy	Gift	Gift	Vule	Vule
Learners Prior Knowledge and Misconception	4	4	4	4	4	4
	4	4	4	4	3	4
Curricular Saliency	3	4	3	4	3	4
	2	4	3	3	3	4
	2	2	2	3	3	3
	3	2	3	2	3	2
What makes the topic difficult to understand	2	2	3	2	3	3
Representation	2	3	3	3	3	3
Teaching strategies	2	2	3	3	3	3

An example of how a disagreement was handled is shown below for the scoring of the component of 'What is difficult to understand' in Table 4.1. I awarded a score of 3 in the category of '*what makes the topic difficult to understand''*, to a pre-service teacher who identified topics that she considered difficult to teach. On comparing the scores across the ratters, the independent raters felt that the teachers should be awarded a 2 (not 3) as the explanation given was hazy. For example, in explaining why the topic is considered difficult to teach the pre-service teacher explanation was too abstract and the reasoning was not related to learner's prior knowledge or misconceptions. Eventually we made a final agreement on which score to award. Where differences occurred these were resolved through discussion. An overall rating agreement of about 89% was obtained, an indication of the reliability of the scoring of the tool.

4.2 TSPCK Scores generated from the rubric at the end of the intervention.

4.2.1 Qualitative generation of scores

The final raw scores that were gathered from the TSPCK post-test using the rubric for each participating pre-service teacher are presented in Table 4.2 below. The first column displays the names assigned to each pre-service that participated in this study. The other five columns represent the five knowledge components of TSPCK under which items in the TSPCK tool were grouped. Alphabets A to E are used to represent the items in each component. The Table below only shows the scores of pre-service teachers after the intervention.

Table 4.2:Pre-service teachers TSPCK raw scores

	TSPCK items						
	Prior knowledge & misconceptions	Curricular saliency	What is difficult or easy	representation	Teaching strategies	Average (individual)	Percentage
CODES	**A/4**	**B/4**	**C**/4	**D**/4	**E**/4		
Jane	4	3	3	2	4	3	80
Gift	4	3	3	3	3	3	80
Newi	2	3	2	2	2	2	55
Mpho	2	3	2	2	2	2	55
ori	4	2	2	3	3	3	70
Kate	4	3	2	3	1	3	65
Abie	4	3	3	3	3	3	80
Muli	4	3	3	2	3	3	75
Vule	4	3	3	3	3	3	80
Kane	4	3	4	3	3	3	85
Xolo	4	4	4	4	4	4	100
Amy	4	3	3	2	4	3	80

Athi	2	3	2	2	2	2	55
Funi	4	3	3	3	3	3	80
Game	3	3	2	3	2	3	65
Zaza	4	3	2	2	3	3	70
Newi	4	2	3	3	1	3	65
Rabe	4	2	2	1	1	2	50
Gale	4	3	3	2	4	3	80
Josh	3	3	2	3	2	3	65
Didi	4	3	3	3	2	3	65
Taki	4	4	4	4	4	4	100
Aggy	4	3	2	2	3	3	70
Kim	4	3	3	3	1	3	70
AVERAGE (component)	**4**	**3**	**3**	**3**	**3**	**3**	**70**

In order to have a better understanding of the overall quality of TSPCK on the data of each individual pre-service teacher the avarage scores were calculated per component as can be seen at the bottom of the table(light blue), and the those of individual pre-service teacher scores were also avaraged in order to get the overall score per teacher and are represented in (yellow). All obtained fractional avarage scores were rounded up or down to the nearest whole number,so that the avarage scores can match with those catergories in the marking rubric.

Although the mathematical avarage was calculated,TSPCK is not the sum of each component,the criteria requares that all the components interact with one another.The overview of avarage was used because it gives an overview of the number sense.

The avarage in the table above shows that the pre-service science teacher Taki and Xolo displayed Exemplary Topic SpecificPCK (rating of 4). From the perspective of the marking rubric this simply means that the pre-service teachers were able to give effective quality responses.This implies that their responses only met criterion 4 in the TSPCK rubric, for example in the case learner prior knowledge item A, in which they (pre-service teachers) were able to identify the misconception and link it to ;learners prior knowledge,they were also able to give the strategy which is effective in improving the error and move the learner towards understanding of the concept.

In addition to that it appears that majority of the pre-service teachers in the remaining four components: carricular saliency, what makes the topic difficult to teach,representation and teaching stratergies, they display Developing PCK (rating of 3). This means that by the end of intervation the pre-service teachers had good understanding of the above mentioned knowledge components. When the validation of the scoring process was complete, the raw scores were then analysed with the Rasch statistical model. This is discussed next.

4.2.2 Quantitative Rasch Analysis

I used Rasch statistical analysis to convert raw scores from TSPCK tool into probability measures that are placed on a linear scale with equal interval units. This feature of the Rasch model allows calculation of the order of item difficulty as experienced by the participants as they engaged with each item (in this case items are TSPCK components) through a topic. According to Boone & Rogan (2005) the advantages of using the Rasch person measures rather than the raw scores of persons is that both the low and the high ends of the scale like the Likert scale in the TSPCK rubric have the greatest margin of error and Rasch person measure gives a more accurate picture of performance as it converts the raw scores into measures that also reflects the probability of the persons to answer a particular item correctly. So by making use of Rasch person measure there is far more important additional analysis possible. In this study, the added benefit of using Rasch was to calculate validity, reliability and establish a sense of the item order of difficulty.

The data was analyzed using software (www.Winsteps.com/ministep.htm) in order to determine the validity and reliability of scores obtained. The Figure 4.1 below reports the reliability information for the persons of the data set as well as added information concerning the item. The total number of the respondents was 24.The concept of reliability is about the extent to which a procedure produces similar results under the same conditions (Bush, 2002). The Rasch model was used to determine both person and item reliability. Figure 4.1 below in the first block (red) report person reliability and the second block report (blue) report the item reliability.

```
-------------------------------------------------------------------------------
| Person       24 INPUT       24 MEASURED               INFIT         OUTFIT   |
|             TOTAL      COUNT      MEASURE  REALSE     IMNSQ   ZSTD  OMNSQ   ZSTD|
| MEAN        14.5        4.8         -.05    1.41      1.20    -.1   1.02    -.1|
| P.SD         2.7         .5         2.57     .67      1.12    1.2    .79    1.0|
| REAL RMSE   1.56 TRUE SD    2.04  SEPARATION  1.31  Person RELIABILITY  .63|
|-------------------------------------------------------------------------------|
| Item         5 INPUT        5 MEASURED                INFIT         OUTFIT   |
|             TOTAL      COUNT      MEASURE  REALSE     IMNSQ   ZSTD  OMNSQ   ZSTD|
| MEAN        69.4       23.2          .00     .52       .98     .0   1.03     .3|
| P.SD        10.1        1.2         1.99     .03       .22     .8    .43     .9|
| REAL RMSE    .52 TRUE SD    1.92  SEPARATION  3.70  Item   RELIABILITY  .93|
-------------------------------------------------------------------------------
Output written to C:\Users\Ezra\Downloads\ZOU295WS.TXT
CODES= 234
```

Figure 4.1: Summary reliability statistics of the Rasch analysis of the TSPCK tool

The findings of the summary statistic indicated that person reliability score is 0.63 and person separation of 1.31 (in the red block), this shows a good level of reliability. While the item reliability score is 0.93 and item separation of 3.70 respectively (in the blue block) which is also acceptable. The scores are measured on a scale of 0 to 1, where the values above 0.6 are generally regarded as acceptable. So, the more closer the person and item scores are close 1, as can be seen above the more statistically reliable they are.

The whole statistic data provide the argument for validity. The only weakness about this data is the sample size that is not big enough, even though there's small sample size the argument for validity is still credible.

The Rach model was used in order to measure the extent of a single construct and in this case it was used to measure the TSPCK of stoichiometry. If the conventional range is between (-2) and (+2) it is considered to be a good fit and an argument for validity .In the Rasch model there's two 'fit' statistics and this are infit and outfit. Firstly, the infit measures the performance of an individual in relations to item difficulty. Therefore if there's a positive correspondence between the person ability and item difficulty it shows construct validity. On the other hand, the outfit statistics used to measure the items that are on the outside person's ability.

The key statistics of this data are the ZSTD (Standardised z- score) and the measure statistics. The Z-Score is a statistical measurement of a score's relationship to the mean in a group of scores. A Z-score of 0 means the score is the same as the mean. The ZSTD range for validity is between -2 and +2. These scores measure to what extent a single construct is being measured by this sample group. The measure statistics indicate how difficult the respondents found the test: the more negative the more difficult the test

TABLE 17.1 TSPCK DATA ZOU295WS.TXT Feb 23 2017 23:12
INPUT: 24 Person 5 Item REPORTED: 24 Person 5 Item 3 CATS MINISTEP 3.90.0

Person: REAL SEP.: 1.31 REL.: .63 ... Item: REAL SEP.: 3.70 REL.: .93

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
11	20	5	5.88	1.92	MAXIMUM MEASURE				.00	.00	100.0	100.0	Xolo
22	20	5	5.88	1.92	MAXIMUM MEASURE				.00	.00	100.0	100.0	Taki
10	17	5	2.05	1.03	1.39	.7	1.22	.6	.40	.61	60.0	72.9	Kane
24	13	4	1.22	1.18	.16	-1.2	.13	-.9	.93	.71	100.0	79.3	kIM
1	16	5	.99	1.02	1.51	.8	1.32	.6	.72	.67	60.0	78.1	Jane
2	16	5	.99	1.02	.15	-1.6	.14	-1.3	.91	.67	100.0	78.1	Gift
7	16	5	.99	1.02	.15	-1.6	.14	-1.3	.91	.67	100.0	78.1	Abie
9	16	5	.99	1.02	.15	-1.6	.14	-1.3	.91	.67	100.0	78.1	Vule
12	16	5	.99	1.02	1.51	.8	1.32	.6	.72	.67	60.0	78.1	Amy
14	16	5	.99	1.02	.15	-1.6	.14	-1.3	.91	.67	100.0	78.1	Funi
19	16	5	.99	1.02	1.51	.8	1.32	.6	.72	.67	60.0	78.1	Gale
8	15	5	.00	.97	.47	-.8	.40	-.9	.88	.70	80.0	71.5	Muli
21	15	5	.00	.97	1.23	.6	1.27	.6	.60	.70	80.0	71.5	Didi
6	12	4	-.04	1.07	.70	-.3	.60	-.4	.85	.73	75.0	68.7	kate
5	14	5	-.90	.93	1.29	.7	1.33	.8	.70	.70	60.0	68.2	Ori
16	14	5	-.90	.93	.40	-1.4	.40	-1.4	.97	.70	100.0	68.2	Zaza
17	14	5	-.90	.93	.40	-1.4	.40	-1.4	.97	.70	100.0	68.2	Newi
23	14	5	-.90	.93	.40	-1.4	.40	-1.4	.97	.70	100.0	68.2	Aggy
15	13	5	-1.78	.95	1.22	.6	1.46	.9	.38	.69	60.0	66.8	Game
20	13	5	-1.78	.95	1.22	.6	1.46	.9	.38	.69	60.0	66.8	Josh
18	8	3	-2.17	1.25	1.21	.5	1.04	.3	.94	.72	33.3	67.4	Rabe
3	11	5	-4.56	1.58	3.73	1.7	2.58	1.3	.04	.70	60.0	91.0	Newi
4	11	5	-4.56	1.58	3.73	1.7	2.58	1.3	.04	.70	60.0	91.0	Mpho
13	11	5	-4.56	1.58	3.73	1.7	2.58	1.3	.04	.70	60.0	91.0	Athi
MEAN	14.5	4.8	-.05	1.16	1.20	-.1	1.02	-.1			75.8	75.3	
P.SD	2.7	.5	2.57	.30	1.12	1.2	.79	1.0			20.2	7.7	

Figure 4.2:The person measure statistic generated by Rasch analysis

The measure scores are mostly positive, which indicates that the respondents found the test manageable. Only 11 respondents have negative measure scores which indicate that they found the assessment to be difficult. Since the TPCK tool was administered to the pre-service teachers, so it would expected that in-service teachers would be able to cope with the level of this test easily.

As can be seen above, in the first column the items were ranked from the most difficult and show statistically question 20 was the most difficult. In the (2nd red column) the measure statistic that gives a numerical value to these difficulties is shown.

The more positive the value the more difficult, negative values indicate easier items. The overall measure statistic for the items was -0.5 indicating that the teachers who completed the TSPCK tool found it manageable.

The Rasch analysis allows for a mapping of person against items, shown below in Figure 4.3. The figure arranges both items and persons along a vertical scale. The items are shown on the right of the map and are arranged vertically from the most difficult to the easiest. The persons are arranged on the left and are ranked from highest to lowest ability.

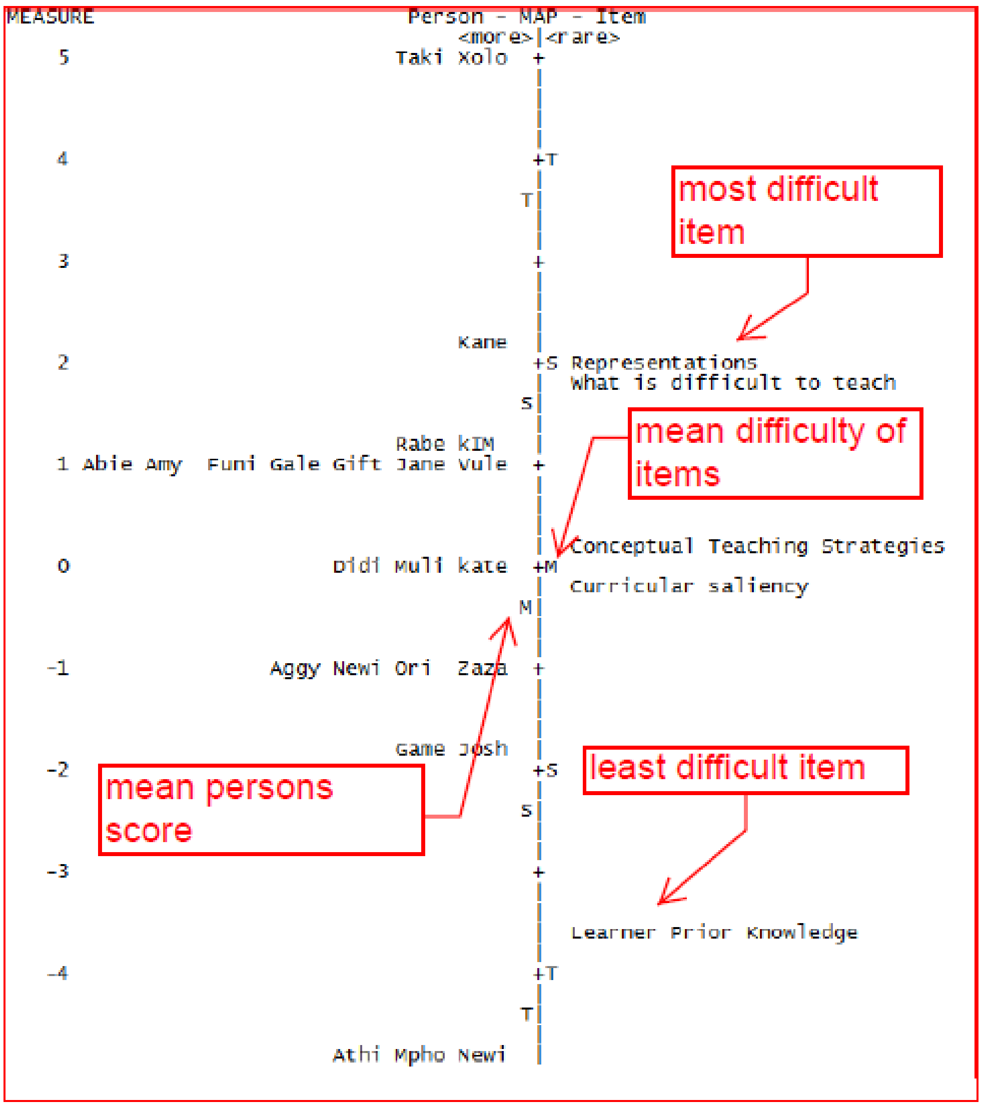


Figure 4.3: Item-Person Map of the TSPCK assessment tool generated by Rasch analysis

The item map above shows graphically that the person's ability is clustered towards the top (above zero). Whereas, the item measures are seen to be clustered in the middle and towards the top of difficulty. It is further, evident from the data above that the pre-service teachers has a good content knowledge in stoichiometry at the end of the intervention and that the TSPCK assessment tool administered to them was not too difficult to answer. As mentioned above the Rach model allows the calculations of reliability. Item reliability is a measure the probability that similar a sample population will produce similar results if they were given the same test and person reliability is a measure of the probability of the this sample population getting similar results if they were given a different tests that measures the same construct. The nearer this value is to one the more reliable it is regarded.

The Rasch scores above confirm the observation made during the analysis that most of the pre-service science teachers struggled in with using '*representations' or 'analogies'* .whereas *learners' 'prior knowledge'* is the least difficult component of TSPCK. The reason of representation component to be regarded as difficult could be the fact that pre-service teachers hardly use models or any representations in practical investigation in the classroom when teaching learners for conceptual comprehension. Most of the lessons on stoichiometry are more theoretically taught and only textbooks diagrams or equations are used for explanations. The ranking of the TSPCK component is different to the one obtained by Mavhunga and Rollnick (2013).The main different is that in their study with in-service teachers on the topic of chemical equilibrium they found conceptual teaching strategies to be the most difficult and representation was ranked equally with curricular saliency. From the item map, it is clear that more than half of the pre-service teachers did give good quality answers to all the questions asked. Majority of them were able to answer the questions fully and they did attempt to answer all the questions. To be precise, the pre-service teachers Taki and Xolo has shown an overall better quality of TSPCK as measured by the TSPCK tool to all the test items including the test items in the representation category .

This simply means that the person whose positions is higher above certain items in the linear scale of the item map have a much higher chance (higher than 50%) to answer that item correctly and vice versa. For example, Game Josh and everybody higher have a more than 50% chance to answer item "Learner Prior Knowledge" correctly. However pre-service teacher Athi, Mpho and

Newi have less than 50% chance to answer the same item correctly. The spread of person measures and items extend across the length of the scale showing good separation of items and persons' measures. This indicates good reliability of both persons and items.

4.3 Qualitative evidence displaying pedagogical transformation in the responses

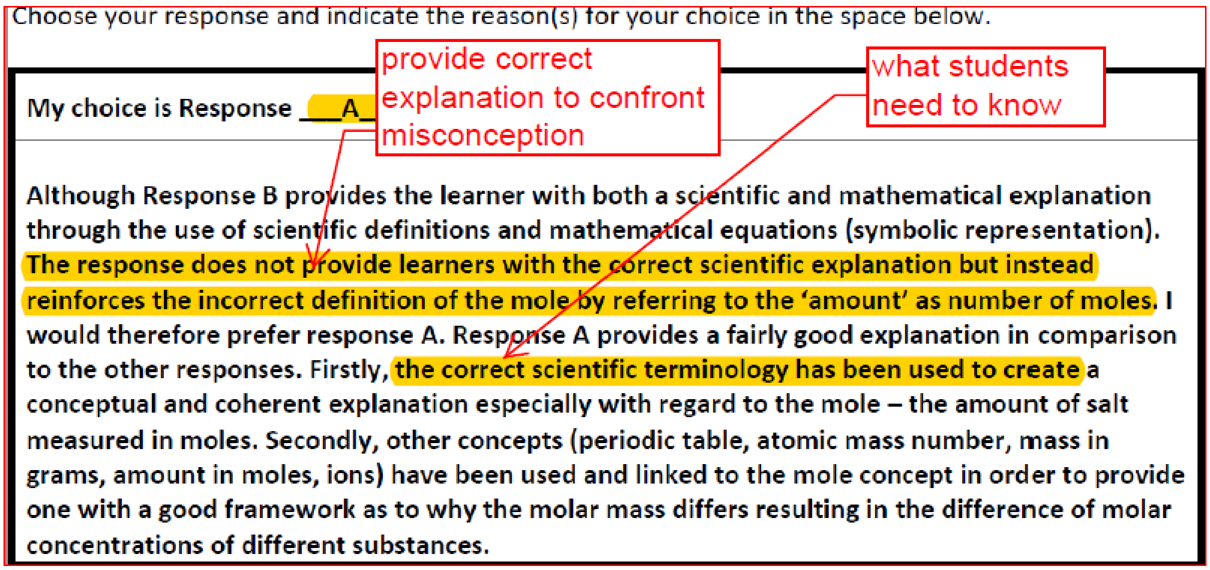
The criteria of the TSPCK rubric refer to interactive use of the one TSPCK component with others. In the PCK literature (e.g. Park Jang,Chen & Jung, 2011) the interaction of components of PCK, irrespective of which model is used, is regarded as an indication of the extent of quality of PCK. This view is demonstrated by Geddis and Wood (1997), who asserted that transformation of content knowledge is achieved when content specific components like those of the TSPCK are known and used in interaction to each other. Thus in this study, the extent in which the TSPCK components are used in the responses provided by the pre-service teachers indicates episodes of pedagogical transformation of content knowledge, and the extent of evidence is then graded according to the quality categories in the TSPCK rubric. Below I will present examples of evidence of cases where pre-service teachers demonstrated interactive use of TSPCK components thus pedagogical transformation of content knowledge.

4.3.1 Evidence of interactive use of TSPCK components in the component: learner's prior knowledge and misconception

The task on the component of Learner Prior Knowledge in the TSPCK tool was that pre-service teachers were asked to comment on a learner response that contained a misconceptions and another involving prior knowledge about the mole concept and concentration.

All the given options in this component are conceptually correct, so the focus is to uncover whether the participants are able to provide the reason behind their precise selection. In addition to that, both items were designed to find whether the pre-service teachers can have recognized and acknowledge learner's misconception and then how the pre-service teacher will respond to that particular question.

The teacher's response and reason in this question will vary according to their knowledge and understanding, the simplest level answer that is expected is for a pre-service teacher to simply repeat the correct answer from the question, or if better the teacher would re-phrase what has been said in the provided options or lastly especially if the knowledge of the teacher is more developed could possible apply more complex method to pick and justify their option drawing on the knowledge of TSPCK components. Below is an example of the response that was obtained from pre-service teacher Xola. The Figure 4.4 is an extract of question.


Choose your response and indicate the reason(s) for your choice in the space below.

My choice is Response ___A_

Although Response B provides the learner with both a scientific and mathematical explanation through the use of scientific definitions and mathematical equations (symbolic representation). The response does not provide learners with the correct scientific explanation but instead reinforces the incorrect definition of the mole by referring to the 'amount' as number of moles. I would therefore prefer response A. Response A provides a fairly good explanation in comparison to the other responses. Firstly, the correct scientific terminology has been used to create a conceptual and coherent explanation especially with regard to the mole – the amount of salt measured in moles. Secondly, other concepts (periodic table, atomic mass number, mass in grams, amount in moles, ions) have been used and linked to the mole concept in order to provide one with a good framework as to why the molar mass differs resulting in the difference of molar concentrations of different substances.

Figure 4.4: An example of a 'developing' response for the component of Learner Prior Knowledge

It is evident that the response from pre-service teacher Xolo in Figure 4.4 above displays the use of two different TSPCK components. From the above response it can be seen that Xolo was able to engage fully with the question as she confronted the incorrect statement and further distinguishes what was done right. Therefore, I believe that this response is more appropriate and it shows teachers with a PCK that is developing. This describes her as a pre-service teacher with understanding of the TSPCK component 'learner's prior knowledge'. In addition to that, is what learners need to know? She put the emphasis of scientific conceptual aspect, therefore this demonstrate her good and understanding of content knowledge in stoichiometry. And this describes her knowledge of TSPCK component 'curricular saliency'. So, this gives an idea that the components are interacting together instead of working in isolation.

Component B: curricular saliency

Amongst all the components curriculum saliency had more items within one component. It is consist of 4 items. In this component the pre-service teachers were given a list of main and subordinate ideas of which they had to identify big ideas then show the sequence in which they will teach them, then show how all those big ideas link to one another and lastly they were asked to identify the topic that require understanding prior teaching stoichiometry.

The selection of the concepts that needs to be taught before teaching this topic as required in the CAPS (Department of Basic Education, 2012) curriculum document and giving the reason why it is important to teach stoichiometry was found to be more challenging items in this components as majority scored level 2 in this two questions which shows that the PCK is basic. The reason for most of them to be on level 2 is because some participants were unable to provide the main pre-concepts to be taught in designated topic and their reason for section did not provide logical link between big ideas and subordinates in such a way that most of them were too general. Showing how the big ideas link to one another and subordinates concepts is on level 3 which is (developing) and lastly Identifying big ideas from the list given to them is on level 4(exemplary) which is the least problematic.

Figure 4.5 below provide a list of the big ideas and the subordinate's concepts which work as a point of reference given within item (B1), the topics that are highlighted in yellow are the ones that are regarded as the main big ideas. The reason I have provided the Figure 4.5 below is that big ideas are crucial in creating a concept map.

Theoretical yield is the amount of product that is formed when a reaction goes to completion based on the stoichiometry of the reaction.	**Molar ratios** can be used to determine the amount of reactants used or the yield of product formed.
Molar Mass of an element or compound expresses the equivalent relationship between one mole of a substance and its mass in grams.	**Balanced chemical equations** provide the combining ratios of reacting substances and their products in a chemical reaction.
Stoichiometric calculations combine balanced chemical equations and the concept of the mole to calculate the masses of all reactants required and products formed in a chemical reaction.	**Molar Volume** of a gaseous substance expresses the equivalent relationship between one mole of a gas and its volume of 22,4dm^3 and standard temperature and pressure.
Conservation of mass is a chemical law that allows quantitative relationships to be established in chemical reactions.	**Dilution** is the process of decreasing the concentration of a solution by addition of solvent to a solution.
Concentration is a property of a solution and relates to the number of solute particles per unit volume. big idea	The amount of substance in a given mass or volume can be expressed as **a constant amount of elementary particles.**
Limiting reagent is the reactant that used up in a chemical reaction and determines the amount of product formed. big idea **Concentrated solutions** have more particles per unit volume than **dilute solutions.**	**The mole** is the SI unit for amount of substance and allows us to connect the macroscopic scale of matter with the microscopic scale of matter and can used to help count elementary particles that make up substances. big idea
The **actual yield** of product formed depends on the reagent that limits the amount of the other reactant that reacts.	Gravimetric and volumetric analysis are **quantitative analysis methods** to determine the amount of substance.
Reaction stoichiometry involves the determination of molar ratios of the amount of reactants and products in a chemical reaction through balanced chemical equations.	**Avogadro's number** expresses the equivalent relationship between one mole of a substance and the number of entities it contains. Avogadro's number has been experimentally determined to be 6,02 x10^{23} particles
Volume is the amount of space occupied by a sample and from the volume of a gaseous substance the amount of substance can be determined.	**Mass** is the amount of matter contained in a sample and from the mass of a chemical substance the amount of substance can be determined.

Figure 4.5: component B list of big ideas and subordinates ideas of item B1

Under this component in this item A1 pre-service teachers provide various responses to the question. Although in certain responses the pre-service teachers mixed the big ideas with subordinate's concept, what I find more fascinating is that most of the participants were able to select big ideas from the list above and provide the sequence that depict the best order of teaching them. Figure 4.6 below shows an example of response obtained from one of the participants.

	Suggested concepts and sequence	Reasons
1.	The mole is the SI unit for amount of substance and allows us to connect the macroscopic scale of matter with the microscopic scale of matter and can used to help count elementary particles that make up substances	The definition contains the most fundamental concepts that would able the teacher to link those concept with the previous lessons in chemistry and the ones that need to follow.so it links the previous knowledge to the future knowledge.so that there would be a better understanding of the concept that would be taught. It also mentions that the mole is the SI unit. It is very important that learners should know that the mole is the SI unit
2.	Concentration is a property of a solution and relates to the number of solute particles per unit volume.	The reason why this is the next concept it's because we have already started introducing the amount of substance to the learners so the concentration of the solution is the measure of how much of amount of substance there is dissolved in a given volume of the solution. This concept links to the other one that's why we followed by it.
3.	Limiting reagent is the reactant that used up in a chemical reaction and determines the amount of product formed.	Learners must know what happens to the reaction and what makes it to stop and why. The reactant in a chemical reaction that limits the amount of product that can be formed. The reaction will stop when all of the limiting reactant Is consumed.

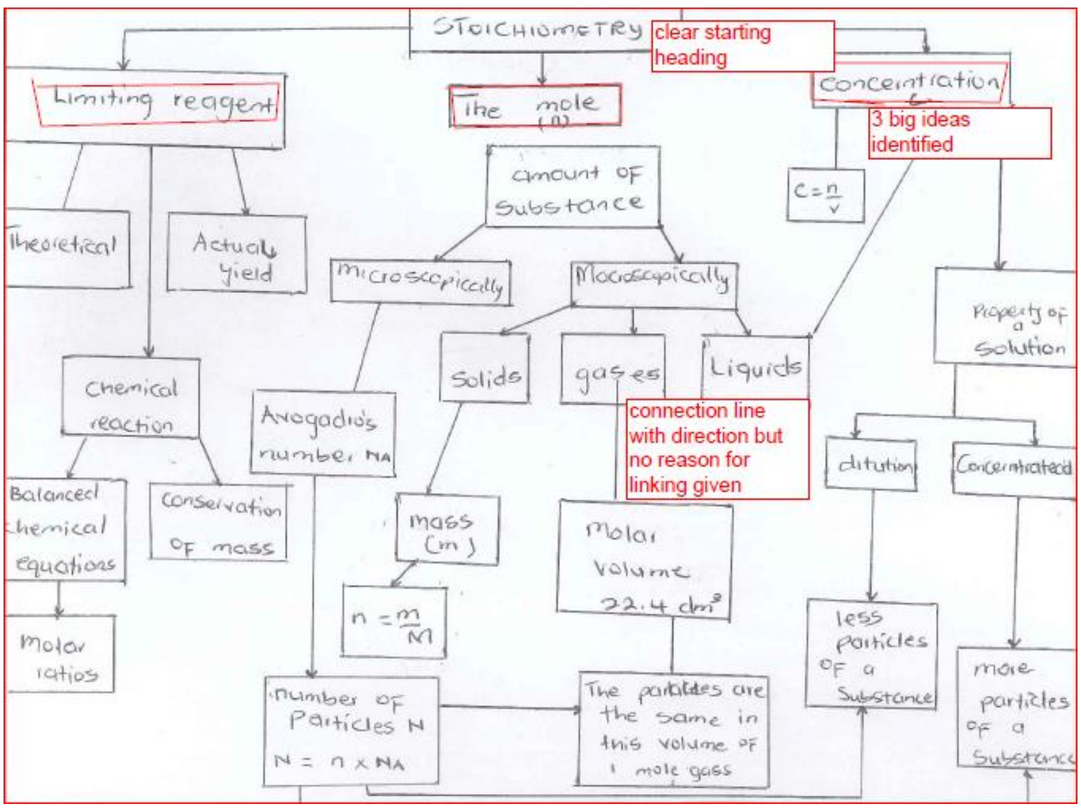


Figure 4.6: Extract from respond Thato

The response in Figure 4.6 above shows that Thato is aware of big ideas in stoichiometry and was able to provide different subordinates under each big idea but he did not show the connection or how they kink to each other. The explanation for the reason for selecting the big ideas in the order given shows sequence development and a good content knowledge of the subject. His concept map fall under category 3 which is developing because there is evidence in his concept map that shows three big ideas but missing connections between them.in addition to that, he was also able to identify the concepts give a brief explanation of the important of teaching stoichiometry which has to do with the relevance in industries and scaffolding for other topics in science such as chemical equilibrium. It was this kind of detailed responses from the pre-service teachers and able to select big ideas that contributed in majority of them to score higher and overall score of 3 for this category. Hence this component was ranked the second least difficult item from the Rasch analysis.

Component C: understanding of what makes topic easy or difficult to understand.

With regard to this component and in relation to the topic of stoichiometry, it is expected that accomplished teacher will find it easy to teach as compare to the novice teachers. In this component pre-service teachers were provided with various concepts in stoichiometry in a table form. From the given concepts, they were asked to select the topics that they think are difficult to teach and substantiate what makes them difficult to teach.

CATEGORY C: UNDERSTANDING OF WHAT MAKES TOPIC EASY OR DIFFICULT TO UNDERSTAND

4. What concepts do you find difficult to teach in stoichiometry? Select your choice and provide reason(s) in the table below.

Concept	✓	Why is it difficult for learners to understand?
Amount of substance/mole		They cannot visualise the concepts.
Molar mass		Can be confused with actual mass
Molar volume		Usually get confused with actual volume
Avogadro's number		Cannot be easily proven and it is a huge number that cannot be easily comprehended.
Concentration		It is based on the particles inside matter which cannot be easily seen
Dilution of solutions		
Molar ratios		Usually confused with the number of substances
Stoichiometric calculations		Since it involves integration of various formulae it becomes difficult

Figure 4.7: Extract from respond Jane

The purpose of this component was to find out if whether the teachers are able to identify the main concepts that are difficult to learn so that they can be able to come up with various teaching methods which will help learners with different learning ability and deepened their conceptual understanding of the concepts. Some of the concepts provided on the list includes amount of mole, molar mass, concentration etc.

Looking at the overall average performance of the teachers in this component, it is evident that they PCK is still developing, they are on level 3 which means that they were able to provide related reasons to specific learner's prior knowledge of which includes their misconceptions. With that said this shows a growth in understanding of which is referred to professional knowledge practice by Loughran, Berry & Mulhall (2012).

Component D: representations/analogies/models

This component is consisting of 1 semi-open item of which is then divided into 4 questions. Pre-service teachers were asked to comment on content representations of mass, mole and number of elementary particles. Based on the given representation they were asked to explain what they like and dislike about each representation and to further explain how they are going to use the representation that they like the most in their teaching practice. The types of representations that were provided include table of items and a flow diagram.

Stoichiometry is regarded as one of the most challenging subject to teach and understand to both the teachers and the learners Dahsah and Coll (2007). Therefore, it is crucial for the novice teachers to understand the quantitative aspect of chemical reactions that are involved in the grade 12 curriculum. Hence, teachers should be familiar with different types of representation they might choose to use in their classrooms. The reason being that different learner's learner in different ways, therefore it is the teacher's responsibility to be able to cater for various learning abilities in order to enhance learner's conceptual understanding? Figure 4.8 below is an example of the representations used.

Looking at the table of raw score the pre-service teachers average is level 3 which means their knowledge is developing. It is evident in Figure 4.8 below of pre-service teacher Taki. In her explanation she was able to incorporate multiply teaching tools like microscopic and macroscopic level by using formulas and periodic table. She was awarded level 3 because she didn't not explicitly show the link between the different kinds of representation that relate to the aspect at hand. Based on her explanation it can be seen that there is growth in her knowledge or understanding of different representation to be used in practice. On the other hand, some of the pre-service teachers in the study portrayed poor understanding of various representations as they did not attempt to answer the question, therefore it can be assumed that they do not know about them and other reasons given were too generic, which means that they were not displaying learner's context. Pre-service teacher Taki did acknowledge that macroscopic and symbolic should be used, this is suggested by her idea of using diagrams that the learners can link to and also made use of visual like socks, eggs cartoons and dice in order to assist her learners in understanding abstract concepts.

I would use this representation to introduce the concept of the mole. I would bring the materials to class and ask students to give the collective name for the group of each, for example, if I have 2 dice or two socks, what do we call this quantity? If I have 2 cartons of eggs, what do I call this quantity? And so forth. As I do this, I will write the table on the board. I will also point out to students how the quantities get bigger, by asking them to note the trend of the size of the amounts. I would use a ream of paper to show the students that a ream of paper is 100 sheets, which is the same amount as 100 smarties; yet their masses are different. This will help students recognise the difference between amount and mass by using everyday examples to straighten out their logic. Finally, I would introduce the mole- as an amount that describes a number of particles or molecules or compounds. I would ask students to give an example of what they think 6.02x10^23 as a number is- they can do this either by trying to write out the number in standard form or by giving an example of something of that amount, for example some students may suggest grains of sand in the world. They can even try to write the number out or count up to it. The scale of the number is very big, which may either overwhelm some students, or be meaningless to others, which is why trying to contextualise the number itself to the students is important. It also gives them a link between the macroscopic and the microscopic aspect of particles, and will help them understand why the quantity is simply referred to as a mole instead of writing actual amounts of substance without the mole as a unit.

use of different materials

I would then extend this introduction by defining the given number as equivalent to Avogadro's constant; and explain to students how the mole is a unit for the number of particles. I will discuss with students how Avogadro's number was determined so that they do not get the conception that the mole is exactly 6.02×10^{23} particles.

macroscopic

use of formulas and periodic table

Lastly, the relationship between mass and the moles will be introduced. This will be done macroscopically, where I show the students the number of different materials; for example 12 beads, 12 pellets, 12 crayons. They will see that the same 'amount' of each substance is present but they occupy different space and also, when weighed; have a different mass. This inculcates the property of the mole as an amount which differs from everyday language where amount can refer to mass. Next, I will give the students 0.1 moles of different substances e.g. carbon, sulphur, iron, calcium oxide. They will note that the amount that can be seen looks different. Next, they will weigh each sample and discover that the masses are different; too. Then , I will relate the masses they found to the periodic table. Students will realise that there is a relation between molar mass on the periodic table and the masses they have found. I will then go on to explain to them why I chose 0.1mole; and what would happen to the mass if I had chosen 1 mole. This extension process will require me to contextualise mathematically to the students, using formulae and the periodic table. This is how I will extend the mole concept to its relationship to mass. The students will be reminded of the mole as a quantity by using the representation and lab activity, which they will be required to copy down and summarise respectively, and add their own examples to. I will expect them to explain to me how the 0.1mol of CO_2 relates to molar mass- this will help them to extend their thinking skills.

Figure 4.8: Example of representation

Component E: Teaching strategies.

Mavhunga and Rollnick (2013) in their research found that the conceptual teaching strategies component is the most difficult one because this component bring together the knowledge of the other components and it require a strategic reasoning. When I look at the participant's levels, although their average is 3, it is the case in my finding but it was determined to be minimal. A possible reason could be that they do not have experience to be able to understand different teaching methods even though they have good content knowledge.

In this component the pre-service teacher were given two learners response about limiting reagent of the reaction. From the responses of mix of correct and incorrect answers, the pre-service teachers were asked to identify learner's errors and to give the teaching method they will employ to assist the learners. Below is two extract from pre-service teacher Ori and Taki.

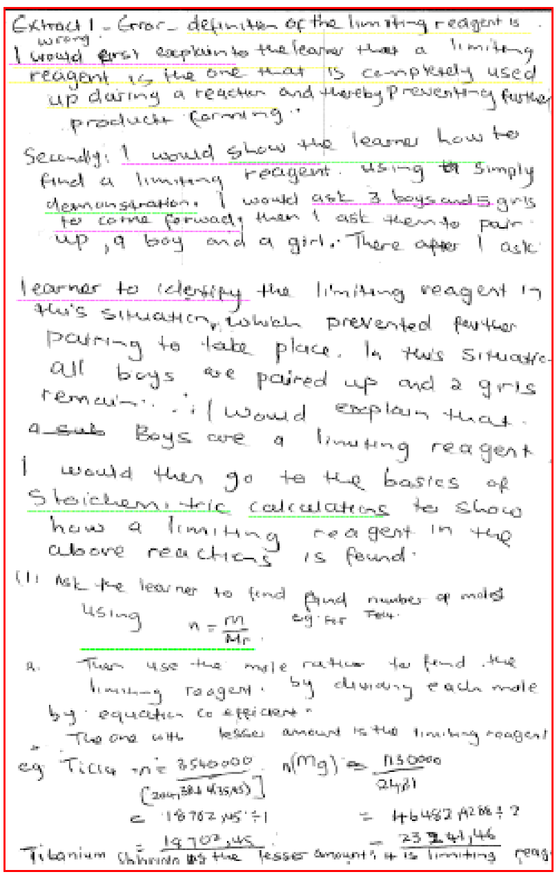

Extract 1 - Error - definition of the limiting reagent is wrong.
I would first explain to the learner that a limiting reagent is the one that is completely used up during a reaction and thereby preventing further product forming.
Secondly: I would show the learner how to find a limiting reagent using simply demonstration. I would ask 3 boys and 5 girls to come forward, then I ask them to pair up, a boy and a girl. There after I ask learner to identify the limiting reagent in this situation, which prevented further pairing to take place. In this situation all boys are paired up and 2 girls remain. ∴ I would explain that ~~a sub~~ Boys are a limiting reagent.
I would then go to the basics of Stoichiometric calculations to show how a limiting reagent in the above reactions is found.
(1) Ask the learner to find find number of moles using $n = \frac{m}{M_r}$ eg for $TiCl_4$.
2. Then use the mole ratio to find the limiting reagent by dividing each mole by equation coefficient.
The one with lesser amount is the limiting reagent.
eg $TiCl_4$ $n = \frac{3540000}{[\ldots]}$ $n(Mg) = \frac{1130000}{24{,}31}$
$= 18702{,}45 \div 1$ $= 46482{,}\ldots \div 2$
$= 18702{,}45$ $= 23241{,}46$
Titanium chloride has the lesser amount ∴ it is limiting reag

Figure 4.9: extract from pre-service teacher Ori

Teacher Ori in the Figure 4.9 above was awarded level 3 which is Developing the reason being that she did not acknowledge learners prior knowledge, instead of identifying the error and correct it, she started by defining the concept. In her explanation she mentioned that the limiting reagent has been identified incorrectly but she does not stipulate more on that. In her teaching she mentioned the use of model and symbolic representation which involve the math's calculations and equations which means that she has used two types of representation to enhance learner's conceptual understanding. In the case where the pre-service teacher left it blank they were awarded with the score of 1, this was done in relation to the categories in the marking rubric as there was no zero.

On the other hand, looking at Figure 4.10 below of teacher Taki, it is evident that she was able to identify area of misconception and did provide the examples of which would help the learners understand the concept around limiting reagent, her lesson is highly learners centered and make use of different kinds teaching methods to address the concept being considered.

The students do not fully understand what limiting reagent is. They understand that it is the reactant that will get used up first and once it is used up; the reaction will not proceed further to form more product; however, the way in which they define the quantity which identifies the limiting reagent is incorrect. In extract 1, the student simply looks at the molar ratios; and decides that the reactant with the smaller molar ratio is the limiting reagent. In extract two, the student believes that the limiting reagent is the one with the least mass. There are a number of ways to dispel these misconceptions.

identify area of misconceptiions

Firstly, I will give the learners a 'recipe' to follow, in order to make a snack. They will require 2 marie biscuits, 2 pieces of chocolate, 6 jelly tots and 2 cherries. However, they will not be given exact amounts but varying amounts of each ingredient. They then have to make up as many full desserts as they can. They then have to make note of how many complete products could be made, and what was left over. This will draw an analogy between limiting reagent and excess reagents as they have to identify which ingredient(s) were limiting reagents and which were in excess.

use of analogy

Next, I will do a demonstration with the learners, using 20g of copper sulphate and 15g of iron. I will also write the balanced equation on the board. I will then ask learners; which is the limiting reagent; to which they will say the iron because it has the smaller mass. Some learners will say there is no limiting reagent because the molar ratios are all the same. I will then add the iron to the copper and tell them to observe what they see. What happens is that the copper gets displaced and forms Cu(s) ; while $FeSO_4$ is formed. There will still be iron left over at the end of the reaction. I will then as students again, if there is a limiting reagent. At this point, they will realize that iron is left over, so it was actually in excess.

multiple teaching strategies selected

I will then ask students to work out the amount of each reactant, in moles. Once they have done so and compared the amounts, they will see that n for Fe=2.68moles and for $CuSO_4$ n=0.125 moles. They will realise that the substance with the least 'amount' (here we will recap what the mole is) is the limiting reagent. I will then ask students to work, from the given equation. They will draw a representation of what they saw (macroscopic); and then draw a representation of the particles reacting; indicating what is left over and what gets used this. They will present their findings to their peers who will have to confirm whether they think that the presenter is correct or incorrect. This allows for peer assessment and the opportunity for learners to convince each other; thus bringing up misconceptions and correct conceptions which I can then elaborate on. They will thus realise that molar ratios do not necessarily indicate the limiting reagent and mass certainly does not.

Lastly, I would present the calculations in a table form which enables learners to quickly work out the amount of product formed, see the molar ratios and the masses in comparison to the other products and reactants. This layout will enable students to see the connections; once they have understood the concepts.

The limiting reagent would be that which; once used up, would cause the reaction to stop since the products would fully form. The amount of the limiting reagent, in moles, needs to be found and needs to correspond to the molar ratios of the products.

I think this strategy will work as it is both procedural, requires thinking on behalf of the learners and covers the procedure in an analytical way. It makes the reasoning behind the calculation clear, which is beneficial and meaningful to learners. The group 'snack activity' and demonstration are important for learners to gain a concrete conception of limiting reagent. The demonstration allows for an opportunity to deepen the learners thinking and relate it the sub microscopic and symbolic arena. Importantly, I would emphasise the difference between the mass, molar ratio and amount of substance and contextualise it to limiting reagents. I would also show students using the table how to calculate the molar ratios and use the information to find out what limiting reagents could be. This will help them to see the relationship between the different quantities being used and minimises confusion

Figure 4.10: Extract from pre-service teacher Taki

Teacher Taki score was the highest, scored a 4 which is Exemplary on the TSPCK rubric, based on his response as can be seen above, he explicitly identify learners error; that they do not fully understand what limiting reagent is. He further outlined the different strategies that he will use to correct that misconception, which includes calculating the amount of substance and make use of ratio from the balance chemical reaction, use of formula and periodic table which is symbolic representation. In addition to that there's evidence of him using macroscopic representation during his lesson where students are required to draw a representation of particles that they saw during laboratory work.

The main difference between the two pre-service teachers Ori and Taki is their level of knowledge about different misconceptions that learners have and the excellent teaching strategies to teach the required concept. Although they both have content knowledge their level of reasoning is distinct. Therefore, form the above responses it can be concluded that having good content knowledge does not guarantee the ability to deliver an effective lesson.

Unlike a novice teacher a well accomplished teacher would be able to identify various teaching methods for a particular concept. As a teacher it is crucial when considering to teach a topic to consider multiple teaching methods that suit it, know about the context of the learners your teaching of which includes their misconceptions and the knowledge they bring to classroom, understand the curriculum in such a way that can be able to link the concepts in that level of learning and also be able to identify the concepts that learners and you as a teacher will find easy or difficult to understand. After being able to identify all the components, it is then where a teacher can select method suitable to tattle learner's misconceptions that learners are facing with.

4.4 Summary

Based on the discussion in this chapter about the quality of TSPCK, the data analysis has shown that the pre-service science teachers were able to transfer learnt pedagogical transformation. In addition to that, even though the observed evidence did not support the theoretical assumption by Mavhunga and Rollnick (2013) indicating that conceptual teaching strategy' component was the most difficult. In this study the most difficult item was found to be 'representation component' of TSPCK. Therefore, the findings confirm another important aspect that indeed this construct of TSPCK is topic level. The pre-service teachers overall average which rate level (3) meaning their

TSPCK is ‘Developing’. It can be said that the pre-service teachers at the end of intervention had much better understanding of the interaction of the TSPCK component.

Chapter Five-Measurement and analysis of science teacher beliefs at the end of the intervention and the relationship between teacher's knowledge and Beliefs

The purpose of this chapter is to provide an analysis of the pre-service science teacher's Beliefs responses to the instrument in order to determine the quality of their responses in the conception of stoichiometry. Lastly the relationship between the measured TSPCK and the quality of pre-service science teacher's Beliefs in their final year of study is investigated.

5.1 Introduction

"Teachers are expected to play a crucial role in changing schools and classrooms. However, they are also viewed as major obstacles to change due to their traditional Beliefs." (Prawat, in Savasci-Acikalin, 2009:5). Many studies on teacher Beliefs over the past few decades have, according to Savasci-Acikalan (2009), focused on Beliefs in a variety of contexts such as constructivism, curriculum, the goals of science education, the nature of science, science, technology and society, as well as on various reform strands. However, a few number of studies on Beliefs have sought to understand teacher Beliefs in relation to their topic specific. Mahmood (2007) opines that Beliefs influence the manner in which the teacher decides on his/her teaching objectives, plans a lesson and evaluates learning in the classroom.

5.2 Quantitative analysis of pre-service science teacher's beliefs

Teacher Beliefs represent individual teacher's ideas about what they think is true and reflect their own prior experiences with science. Luft and Roehrig (2007) state that "within the last 15 years, understanding and describing teacher beliefs have become a priority for educational researchers. These personal constructs can provide an understanding of a teacher's practice: they can guide instructional decisions, influence classroom management, and serve as a lens of understanding for classroom events (Jones and Carter, 2007, p. 38).

The science teachers Beliefs mini tool which is described fully in chapter 3 is composed of seven questions (see Appendix 9). It was administered to the pre-service teachers as pre and post intervention but for the purpose of this study I will only focus on the post intervention responses. The tool was given to the participants in the same session as the TSPCK tool and in similar manner. Only 12 of the pre-service teachers returned the tool unlike 24 who completed the TSPCK tool. The pre-service teachers took about 30 minutes to complete the tool and all were given distinct codes.

For the evaluation of the science teacher's Beliefs tool, I used Beliefs maps. Before the marking commenced me and other two raters sat together and agreed on the correct answers to the questions, in relation to the description of each category. After agreeing on the rules and procedures for scoring, each researcher went ahead and scored their individual two questionnaires.

A modified form of Luft and Roehrig (2007) was administered to the pre-service teachers and it was analyzed using the Beliefs maps categories. Below is an extract of the questions given to the pre-service teachers during the intervention.

INDIVIDUAL TASK

Based on the group task and the selection of the Big Ideas, write an essay (4 – 5 pages) on how you would teach the mole. Structure your essay according to the five categories of the proposed teaching model. Your essay needs to highlight:

(1) What are your beliefs about teaching chemistry? To help you complete the 'teacher belief tool. **(2)**

(2) What is your strategic long term plan in teaching the mole? In other words, what important concepts do you need to cover before teaching the mole? Explain how these concepts are used when teaching stoichiometry. **(3)**

(3) What is your tacit plan for teaching the mole? In other words, why is an understanding of the mole concept important? Think about what topics require an understanding of stoichiometry and explain which concepts are needed. Why is it important to learn about stoichiometry? **(5)**

(4) What is your tacit realization in teaching the mole? In other words, which Big Idea would you start with, and why in helping learners understand the mole concept. Justify your selection of this Big Idea with confirmation statements. State which concepts/skills and activities from the CAPS curriculum you would use in teaching this Big Idea. **(5)**

(5) What is your application for teaching the mole? In other words, which Big Ideas would you sequence after teaching the first Big Idea in order to help learners understand the application of the mole concept in stoichiometry? Justify your selection and sequencing with confirmation statements.
State which concepts/skills and activities from the CAPS curriculum you would use in teaching these Big Ideas. **(5)**

Figure 5.1: pre-service science teacher Beliefs questions

The level of understanding pre-service science teacher's Beliefs was measured. A questionnaire with seven questions, targeting their personal views on teaching stoichiometry was used. Although the pre-service science teachers have been exposed to an intervention and have similar knowledge, they may teach or deliver their lesson differently. The science teacher Belief tool was administered to the participants at the end of the intervention in the same session as the TSPCK tool. Only twelve (12) pre-service teachers returned the Belief tool. The responses to the questions were captured as written responses and they were all given different names.

The responses were scored using the belief maps that was developed and validated by (Luft & Roehrig, 2007). The Belief maps have five different categories Teacher-Centered responses were identified as “(1) Traditional” or “(2) Instructive” beliefs. “(4) Responsive” and “(5) Reform-based” answers were identified as student-centered Beliefs, and responses that indicated primarily behaviorist and affective student attributes were characterized as “(3) Transitional” (Luft & Roehrig, 2007). Below is a Belief map of question six (6) and the rest of the maps can be seen in the attached Appendix 10. The total score of the tool was out of 35 which mean that out of 7 questions, one question weight score of 5.

Below is an extract showing one of the questions in the test items, describing the categories in the map used to assess pre-service teachers.

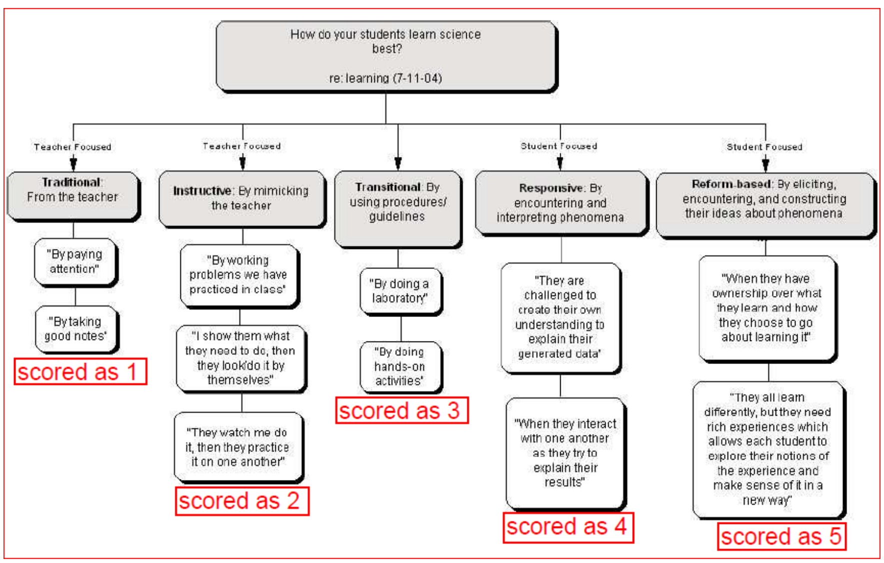


Figure 5.2: pre-service science teacher’s beliefs map

The pre-service teacher’s responses were assessed and matched in relation to the descriptions of criteria in the beliefs map. The purpose of this tool was to elicit the kinds of beliefs pre-service teachers hold about teaching stoichiometry. According to Luft and Roehrig (2007) argues that for one to understand teachers practice, epistemological beliefs have to critical play a role as teachers will implement strategies according to their Beliefs, as it can be seen on the TBI above traditional responses reveal science as based on facts, rules, and methods that are transferable; Transitional responses represent science as a body of certain knowledge; while Reform-based responses support science as a dynamic field that is subject to revision.

Below is Table 5.1 for individual pre-service teachers question by question.
The first column shows the codes given to each pre-service teacher. The table consists of seven questions of which comprises the description of different categories of Beliefs.Q1 to Q7 is used in order to represent the question number. The total scores of the beliefs tool were 35 marks and all the scores were converted into percentage in order to see overall performance per question. In order to have a better understanding of the overall nature of Beliefs of each indvidual teacher the avarage score was calculated per catergoty as shown at the boom of the table.

Table 5.1: Raw scores of science teacher Beliefs

	Questions in science teachers beliefs tool								
CODES	**Q1**/5 Increasing chances for students to learn	**Q2**/5 Perceiving role as science teacher	**Q3**/5 Knowing when students are understandin g	**Q4**/5 Deciding what to teach and what not to teach	**Q5**/5 Deciding to move on to a new topic	**Q6**/5 Knowing when students learn science best	**Q7**/5 Knowing when learning is occurring in your classroo m	**To tal = 35**	**%**
Jane	5	4	5	4	5	5	4	32	**91**
Gift	3	4	3	5	5	3	5	30	**86**
Newi	2	2	1	1	1	1	1	9	**26**
Mpho	1	2	1	2	3	2	2	13	**37**
ori	5	4	3	2	4	4	4	26	**74**
Kate	3	3	3	2	1	2	2	16	**46**
Abie	2	2	2	3	1	1	3	14	**40**
Muli	4	3	3	2	2	2	2	18	**51**
Vule	3	3	2	1	2	2	3	16	**46**
Kane	2	5	3	2	3	2	3	20	**57**
Xolo	3	5	5	3	4	2	3	22	**63**
Amy	2	4	3	2	2	2	3	18	**51**
AVERAGE	**3**	**3**	**3**	**2**	**3**	**2**	**3**		

From the table above it appears that pre-service science teachers experience some difficulties in some of the beliefs items. The most noticeable challenge in Beliefs is seen with the question regarding *‘deciding what to teach and what not to teach’* corresponding to question 4 and question 6 which is *‘Knowing when students learn science best’* respectively. Both questions were scored level 2 which mean the beliefs is instructive, meaning that the teachers in this category are still teacher centered and view science as a rule or fact. However, all the pre-service teachers in the remaining categories fall under level 3 which is ‘Transitional’. Based on the Beliefs map criteria this simply means that the teachers in this category see science as consistent and connected. In addition to that, in their classroom they do what students like to do, they guide them instead of feeding them with information in their development of understanding.

Pre-service teachers because of their lack of experience they bring with them the nature of learning and how it should be taught. However, Geddis and Wood (1997) argued that the teachers that have developed PCK they believe that transforming their own understanding of concept is crucial in teaching. For this research the pre-service teachers were tested on their content knowledge of teaching stoichiometry.

Beliefs about teaching are already established by the time pre-service teachers enter teacher training institutions (Epler, 2011). On their part, pre-service teachers already hold beliefs about teaching and learning – including the Belief that good teaching is highly related to one’s content knowledge and one’s abilities to pass that knowledge to others, when they enter teacher training institutions (Feiman-Nemser, 1996). By the same token, student teachers’ beliefs related to knowledge acquisition develop before their formal entry into the teaching and learning profession (Cheng, et al., 2009). These observations suggest that knowing pre-service teachers’ Beliefs about knowledge, teaching and learning is important because these Beliefs are crucial in their own learning and pedagogical understanding, as well as in their teaching methods and classroom practice (Uzuntiryaki & Boz, 2007).

Given below is an extract of written response of pre-service teacher Xolo for the third question in the teacher’s beliefs tool.

3. Describe how you perceive your role as a science teacher? 5
As a science teacher I firmly believe that my role is to stimulate learners' interest for the love of science (change their attitudes and create positive motivation) through meaningful teaching whereby the content is successfully transformed in an appropriate way (through the five components of TSPCK) to develop learners' scientific knowledge and awareness about the nature of things. My role is to not only transcend knowledge but to also make the content relevant to the learners in a way that has been strategically planned to awaken and build learners' abilities to further inquire, question (as I challenge their thinking) and further contribute to the knowledge of science as science is not 'complete' and new discoveries are made all the time.

Figure 5.3: Extract form pre-service teacher Xolo

The pre-service science teachers were asked to explain what teaching science means to them. It was asked specifically in order to identify what teaching mean to them. A student centered respond is observed from pre-service teacher Xolo. She emphasizes on transforming learner's conceptual understanding of the concept and relates it to their prior knowledge. Therefore, her response shows 'reformed-based' Belief and for that she was awarded level 5 because she is constructivist in a manner that she does not feed them with information but rather help the students make sense of their surrounding in a manner that they can relate to their everyday experience.

5. In a school setting, how would you decide what to teach and what not to teach? 5
I would firstly need to consult my set curriculum from the Department to know what science topics I am expected to cover as part of the syllabus that has been designed/constructed and approved of according to the institution. Thereafter, I would need to research the learners' progression to know what they have already been taught so that I can identify what still needs to be taught in order for them to understand the
next topic. However prior to this I would need to take the topic(s) that I am expected to teach and identify the big ideas – that is the main/core concepts that are to be covered and its peripheral concepts so that the pre-concepts (as mentioned above) can also be identified to see where one would actually start to teach the actual topic – that is what to teach and what not to teach.

Figure 5.4: Extract from pre-service teacher

In order for a teacher to decide on what to teach and what not teach must really have a good content knowledge and be aware of the curriculum. The above respond indicates that this pre-service teacher's Belief shows a positive development towards 'reformed' based which is level 5. The reason being that, although there are several things that can make a topic difficult to teach, she did show the ability to know what's appropriate for teaching a particular grade level and misconceptions for learners or conceptual difficulties. Furthermore, she showed the need for transformation and focus on the learners rather than the teacher-centered method of teaching. Literature also suggests that pre-service teachers with advanced Beliefs use multiple student teaching methods including class discussions, peer teaching, collaborative groups, and also high-order questioning techniques in their science classes and all that is evident in the pre-service teacher above. On the other hand, pre-service teachers with naive epistemological and intelligence Beliefs are known to use teacher- centered methods such as lectures, demonstrations and teacher-led discussions (Epler, 2011) such as pre-service teacher Newi below.

Unlike pre-service teacher Xolo in the Figure 5.3 above a different development in Beliefs is seen in pre-service teacher Newi below.

4. During a stoichiometry lesson, how would you know when your students understand?
A proper eye contact with the learners will show that the students understand or they are lost. For example, some students will nod to show that they understand what the teacher is explaining. Some students will display a confused face to show that they are not following. Proper questioning will also help see how many learners understands; written or verbal.

Figure 5.5: Extract from pre-service teacher Newi

In this case, the pre-service teacher response shows a Belief where the teacher depends on physical appearance (eye contact) in order to know if he's to move on a knew topic or not. It is evident that he's Beliefs did not change even after the intervention; therefore, I assume that it has become a core Belief of which will now guide him through knowledge acquisition and practice. The content of his Beliefs reflect traditional related kind of Beliefs which is teacher-centered in a way that learner's engagement and prior knowledge is not considered.

The post teacher's Beliefs score as seen in the Table 5.1 above were converted into category frequency scores for each and every pre-service teacher who took part. In order to convert all the scores, they were done by placing the same numerical scores in the category they correspond with in the teacher's Beliefs map. For instant all scores of 1 were placed in the traditional category, all scores of 2 in the instructive category, up to the last category. Each value was represented by an asterisk (*) in the suitable category. The number of the asterisks in each category indicates the number of responses to the questions.

Table 5.2: Pre-service teachers Beliefs profile

Post-test beliefs scores					
persons	**Traditional**	**Instructional**	**Transitional**	**Responsive**	**Reform-based**
Jane				***	****
Gift			**	*	****
Ori			**	****	*
Kane		*	******		*
Xolo		**	***	*	*
Muli		****	**	*	
Amy		****	**	*	
Kate		*****	**		
Vule	*	***	***		
Abie	**	**	***		
Mpho	**	***	**		
Newi	*****	**			

The pre-service teacher's Beliefs are mostly in one direction (right side of the table) which is students centered. Most of the pre-service teacher's responses are located in instructional and transitional Beliefs. However, it appears that even after the intervention some of pre-service teachers highlighted in red predominately displayed traditional method of teaching.

5.3 Relationship between pre-service teachers TSPCK and beliefs.

In order to investigate the relationship between pre-service teachers TSPCK and the kinds of Beliefs the two construct were compared. Some of the participants did not complete the Beliefs tool, therefore the results below show data of those who completed both tools at the end of the intervention.

Table 5.3 below shows TSPCK person measures and teacher's Beliefs scores per person. The scores were then entered into a scatterplot in order to show the relationships between two construct.

Table 5.3: Comparison between categories of TSPCK and Beliefs

	TSPCK	Beliefs
Jane	1.0	91
Gift	1.0	86
Newi	-4.7	26
Mpho	-4.7	37
ori	-0.9	74
Kate	-0.1	46
Abie	1.0	40
Muli	-0.0	51
Vule	1.0	46
Kane	2.1	57
Amy	1.0	51

Figure 5.3 below displays a scatterplot where 1st quadrant represents strong TSPCK and Beliefs, 2nd quadrant represents strong TSPCK and weak Beliefs, 3rd quadrant represent weak TSPCK and Beliefs and the 4th quadrant represent strong Beliefs and weak TSPCK.

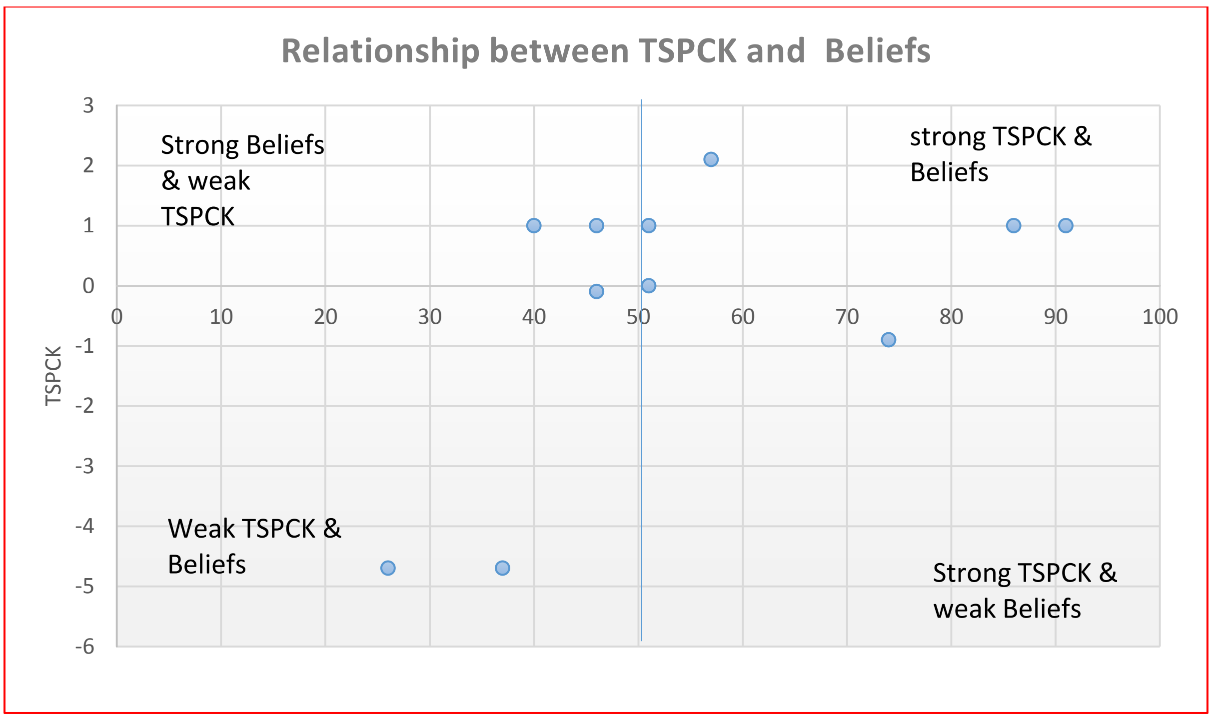


Figure 5.3: TSPCK and Beliefs scatterplot

Based on the cut of point, as can be seen in the Figure 5.3 above, it indicate that slightly above half the pre-service teachers out of 12 possessed reasonable high TSPCK and learners-centered beliefs, five of them are Jane, Gift, Muli , Kane and Amy. So it can be said that pre-service teachers with learner-centered Beliefs may yield high TSPCK. On the other hand, the other three pre-service teachers Kate, Abbie and Vule displayed instructive Beliefs and they portrayed weak TSPCK. Newi and Mpho displayed very low TSPCK and traditional Beliefs this is because they have weak content knowledge of the topic. Therefore, it can be said that teachers with poor content knowledge and teacher centered Beliefs may not yield high TSPCK.

Teachers with high TSPCK showed more learner centered Beliefs and those with low TSPCK showed teacher centered Beliefs. Most of these teachers as can be seen in the Table 5.2 above are in between instructional and transitional Beliefs.

Pre-service teacher Gift and Jane who's TSPCK is higher than the rest of the participants held reformed base Beliefs. Whereas those other teachers who showed relatively high TSPCK most of them either held instructive or transitional Beliefs but not every pre-service teacher with these Beliefs portrayed high TSPCK. All in all, the Beliefs held by majority of these pre-service teachers were between instructive which is teacher-centered and transitional.

The pre-service teacher profiles for TSPCK were prepared in a similar manner as for Belief profiles above. The scores for each and every participant are placed in numerical order in relation to the components on the TSPCK rubric. Only those that have completed both tools have been highlighted in the table below. The generated pre-service teacher TSPCK patterns are shown in Figure 5.4 below.

Table 5.4: TSPCK pre-service teacher's profile

persons	Limited	Basic	Developing	Exemplary
Taki				*****
Xolo				*****
Kane			***	**
Gift			****	*
Abie			****	*
Vule			****	*
Funi			****	*
Amy		*	**	**
Jane		*	**	**

Gale		*	**	**
Muli		*	***	*
Didi		*	***	*
Aggy		**	**	*
Zaza		**	**	*
Newi	*	*	**	*
ori	*	**	*	*
Kate	*	**	*	*
Rabe	**	**		*
Game		**	***	
Josh		**	***	
Mpho		****	*	

At the end of the intervention pre-service teachers predominately displayed a developing and exemplary level of quality of Topic Specific PCK. In examining Table 5.4 above, it can be seen that most of the pre-service teachers have developing or has gained TSPCK as highlighted in yellow. Only three pre-service teachers out of twelve who took part experience no gained in TSPCK as they portray basic level and are highlighted in red. These are pre-service teacher Newi, Ori and Kate.

In comparing the pre-service teacher Beliefs profile and their TSPCK profile it can be seen that some of the pre-service teachers like Gift have displayed more reformed-based Beliefs as well as the developing/ exemplary quality of Topic Specific PCK. However, the relationship between the pre-service teacher's Beliefs and their knowledge of teaching a specific topic is not so smooth the reason being that there's pre-service teachers like Vule, Abbie and Mpho who is still holding the traditional Beliefs but their quality of TSPCK is either developing or Exemplary. Similar to Xolo and kane they show developing/exemplary TSPCK but have one category that is still registering instructive Beliefs. Furthermore, there's pre-service teacher Newi who displayed both poor TSPCK and Beliefs, this simply means that she retained her teacher-centered method of teaching and no transformation in content knowledge of stoichiometry.

5.4 summary

The discussion in this chapter about the science teacher's Beliefs revels that some of the teachers had challenges in answering some of the questions. Some teachers were found to be holding teacher centered Beliefs whereas others are holding students-centered Beliefs. When it comes to the relationship between the constructs under investigation it was found that Beliefs found in the presence of PCK are likely to be student-centered vice versa.

Chapter Six - Discussion of findings, implications of results and conclusion

The following chapter aim to discuss the overview of how the study was conducted and to discuss the findings in relation to the questions that guide the study. The implication of the study are discussed, of which is followed by the recommendation of the future research, reflection of the study and a final conclusion.

6.1 Introduction

Stoichiometry is regarded as a difficult subject to teach and understand due to its complexity (Mitchell & Gunstone, 1984).For this reason learners tend to perform poorly in this section and various literature shows that learners in different countries including South Africa hold quite number of conceptions and misconceptions about stoichiometry and majority of the learners struggle to solve stoichiometric problems (DBE,2011;2013;2014).It has been suggested that teachers are the main source of this misconceptions that learners bring into the classroom of which add into the misconceptions that learners get from the textbook and their everyday knowledge. According to (Calik and Ayas, 2005) pre-service teachers do not fully hold good quality of subject matter knowledge and believe that their existing conceptions are correct, therefore they may spread those misconceptions to their learners. This suggests the need to examine the relationship between the quality of PCK in stoichiometry and the science teacher beliefs of pre-service teachers in their final year of study.

6.2 Methodology Overview

In order to answer the research questions that the study sought to answer a mixed method approach (MM) was used, and the approach is situated in pragmatism. The data collected was analyzed and interpreted using both qualitative and quantitative approach. MM was used because it helped me in understanding better the topic specific nature of PCK. In addition to that, the designed tool required that both narrative and numeric approaches to be used. The use of mixed method has helped me to understanding better the relationship between TSPCK and science teacher’s Beliefs.

Two instruments were used to collect data in this study. The first instrument was TSPCK instrument in stoichiometry and was used to determine the quality of TSPCK in pre-service teachers in their final year of study. The participant's responses were assessed using a rubric in order to give scores for each of the five components of TSPCK. The second instrument was the science teachers' Beliefs and it was used to measure the kind of Beliefs pre-service teachers hold in stoichiometry. The responses to science teacher's Beliefs were scored using Beliefs map. Both instruments were used to measure the quality pre-service teachers TSPCK and science teacher's Beliefs responses and to investigate the relationship that exist between the teacher's knowledge and their Beliefs. The Rasch statistic model was used in order to identify the validity and reliability of the tool used. The following discussing shows the manner in which each question was answered.

6.3 Findings of the study

Research question 1

What is the quality of PCK in Stoichiometry of chemistry pre-service teachers at the end of an intervention in the chemistry methodology course?

The answer to this research question is that there is a significant improvement in the quality of Topic Specific PCK in pre-service teachers at the end of intervention when they are exposed to discussions about transformation of Stoichiometry. The pre-service teachers TSPCK was located in the 'Developing' category of the TSPCK rubric (level 3). A 'Developing' quality category of TSPCK found means that pre-service teachers have improved their understanding of knowledge in TSPCK components that enable them to transform the subject matter knowledge of stoichiometry. The pre-service teachers are at the level of reasoning about the teaching of the topic. It therefore reflects improved thoughts on a sequence of aspects related to stoichiometry concepts, specifically the structuring the topic into its big ideas and provide logical sequence and how the subordinate's ideas link to one another, learners' common misconceptions or learner's prior knowledge and expand their explanations using some of the TSPCK components interactively, identifying areas of difficulty in understanding, representations and analogies, and conceptual strategies to teaching the topic.

Research question 2

What kinds of science teacher Beliefs are held by the pre-service teachers at the end of the intervention?

The answer to this question is that from the data collected the emergent category of Beliefs is that majority of the pre-service teachers were found to hold 'Transitional' Beliefs which is level 3 (see Table 5.1). With this kind of Beliefs according to the science teachers Beliefs maps (Luft & Roehrig, 2007) since majority of the teachers hold 'Transitional' Beliefs they are likely to have instructive (teacher-centered) or responsive (students-centered) Beliefs. Therefore, it can be said that pre-service teachers at the end of intervention were found to have mix Beliefs.

Research question 3

What is the nature of the relationship between their quality of PCK in Stoichiometry and the science teacher Beliefs?

In exploring the third question about the comparison between the science teacher's knowledge and their Beliefs has revealed an independent nature of the relationship between the two constructs. (by independent nature, meant that the two construct do not sorely dependent on one another). The findings revealed that the relationship between the quality of TSPCK and science teacher's Beliefs was independent. Pre-service teachers with a functional "Developing' quality of Topic Specific PCK was found to hold both students-centered and teacher-centered science teacher Beliefs.

6.4 Discussion of the findings and implications

- For the pre-service teachers to have a 'Developing' TSPCK in their final year of study implies that at the end of intervention they were able to give effective quality response to the tool drawing on more than three components of TSPCK interactely rather than focusing on an individual component.According to Mavhunga (2014) argued that when the TSPCK component interaction it is a good indicator of the quality of TSPCK in a topic. This kind of quality of TSPCK I consider functional, as it will enable the pre-service teacher to achieve with reasonable probability effective teaching although not yet exemplary.

- The implication of this finding to the pre-service teachers is that PCK can be transferrable to other topics in science and it will enable them to be able to transform learner's conceptual understanding of the concepts. In addition to that, it means that the idea of influencing the grounds or reasons for a teacher's decisions is desirable when they have quality of PCK (Shulman, 1987, p 17).

- Pre-service teachers have mix of science teachers Beliefs proves the finding of Luft and Roerigh (2007) that science teacher's Beliefs are more likely to change their Beliefs than those of the in-service teachers. The reason being that most of the pre-service teachers they have not had many years of teaching experience with individual learners with different learning abilities and the construction of stoichiometry understanding with learner. In addition to that Pajares (1992) argue that teachers enter the teaching profession with their own understanding of how to teach and how students learn and these experience beliefs play a role on how they teach.

- Feiman and Nemser (2001) The implication for school teaching and pre-service teachers programmes is that they should include rich content in their teaching that nurture students centered Beliefs, in order for pre-service teachers to have an experience of that as a learner themselves.

- Again, this is not surprising as pre-service science teachers have to deal with the conflict between their deeply embedded traditional Beliefs and the ideas that advocate reform-based practices presented in the programme (Karaman & Karaman, 2013). This notwithstanding, the findings of this study have serious and far-reaching implications for the B.Ed science programme. One of these is that the B.Ed science programme should focus on explicitly developing pre-service science teachers' students-centered Beliefs by presenting students with opportunities to identify and evaluate their students-centered bBeliefs about science (Jackson, 2010). Jackson argues that because students are not afforded these opportunities, they are not aware of the tremendous impact these Beliefs have on the instructional techniques they use, and they also have difficulty developing positive Beliefs in implementing student-centered teaching methods (Yilmaz,Tuzun &

Topcu, 2013). The development of the pre-service teachers' epistemological Beliefs during the course of study as being critical for them to be able to apply appropriate teaching strategies for their learners. The programme should also model a teaching and learning environment that is consistent with the constructivist approach (Cheng, et al., 2009). The programme should model reflective thinking and judgment instead of encouraging passive reception of knowledge from authority figures (Cheng, et al., 2009). Cheng, et al, caution that the success of the programme in implementing a constructivist approach in teaching practice depends a great deal on conditions at the placement schools. They argue that schools which have not bought into this constructivist philosophy of teaching and learning are not likely to provide the necessary support to the student teachers placed in their schools, as mentors in schools would be lacking the necessary skills to support the students.

- For the pre-service science teachers to have an independent relationship between quality of TSPCK and science teachers Beliefs it implies that present of quality of TSPCK does not necessarily means that a teacher will lean on responsive and reform based kinds of Beliefs as preferred or holding students centered Beliefs will guarantee one to have quality of TSPCK. The pre-service teachers that hold students centered Beliefs (responsive and reformed based) when comparing the teacher's profiles, they didn't really correspond with level 3 (developing) and level 4 (Exemplary) TSPCK. This simply means that it is possible for pre-service teachers to have good quality of PCK and hold either students-centered or teacher-centered Beliefs about teaching stoichiometry.

- The implications with this findings according to Mavhunga (2012) is that the pre-service teachers during the lesson they will be able to acknowledge learner's prior knowledge or misconceptions about the topic, be organized it terms of the big ideas of that topic and be able to differentiate what important for the learners to know and what's not with the use of representations and conceptual teaching strategies. However, all this will be in the head of the teacher instead of the learners to acquire their own knowledge. With regards to the pre-service science teachers is that they can have quality of TSPCK and hold students centered Beliefs. The implication is that the student centered beliefs are likely to promote reformed based Belief of which is what is required from the teachers.

6.5 Reflection on Trustworthiness and validity for qualitative and quantitative data

6.5.1Trustworthiness for qualitative data

For qualitative trustworthiness and validity I first marked the pre-service teachers' responses using an approved TSPCK rubric and Beliefs map. I analyzed the responses in light of their engagement with the question, then graded each pre-service teachers' response that matched a certain criterion according to the TSPCK level they displayed; and the beliefs category the in the Beliefs maps. Before scoring, two peers to from the same PCK team were asked to rate the pre-service teachers' responses from both instruments and they agreed.The peers were given the TSPCK instrument, with the rubric criteria as well as the rating criteria and Beliefs instrument with Beliefs maps that show rating of each category. After they had familiarized themselves with the rubric and Beliefs maps, the criteria for scoring and their expectations were explained., This was done to check if the rating was consistent with mine, with regard to the similar scores for the same response or not. The peers consisted of one doctoral student and one physical science teacher who has experience in teaching stoichiometry in grade 12 and was also doing a Master's degree. Both were registered at the University of the Witwatersrand.

6.5.2 Validity for quantitative data

Validity and trustworthiness are important issues in the analysis of quantitative data. Validity has been described in different ways by many researchers. According to Kane (2006), he describes validity to be a property of proposed interpretations and uses of test scores. Literature indicates that the process of validating an instrument differs in respect of what aspect of validity is being assessed. Since there are many ways of validating instruments, for this study; the validity of the tool is argued based on the principle which requires both interpretive and statistical validity analysis as arguments. In validation of the TSPCK and Science Teachers' Beliefs instrument, I checked if the empirical evidence agrees with theoretical predictions which are outlined in chapter 2. For the validity argument for TSPCK as a construct, a Rasch statistical model was used in this study to validate the instrument used and also to obtain estimates of reliability. In addition, the Rasch model was used to convert raw scores from the TSPCK instrument only into interval measures of teacher competence. I looked for evidence from the pre-service teachers

Beliefs profile analysis, placing all similar numerical score values in the corresponding category on the Belief map that supports only the theoretical implications.

6.6 Limitation of the study

While conducting the research I encounter some challenges. I acknowledge the limitation of my sample for the study; only few students voluntarily participate. The sample size of 24 on TSPCK tool and 12 for science teacher's Beliefs is not enough to gather statistical data on reliability. In addition to that, this study was limited to testing pre-service teachers reasoning about transforming learner's content knowledge in stoichiometry at the end of intervention which means that they were not actually observed in the classroom teaching. According to Park and Oliver (2008) argued that teachers PCK can be shown only during the transformation of content knowledge, in the classroom where the teacher is teaching, reflecting on what is difficult or easy to learn with that specific group of learners.

Some of the pre-service teachers did not answer all the questions asked, so it was difficult for me to draw conclusion because I did not know if the students lack knowledge, whether the question was too difficult or it was because of time management to complete the task. Thus, from this result it follows that I cannot make a general claim about all pre-service teachers. However, my study confirms several points made in the literature.

6.7 Recommendation

Literature has retrieved that stoichiometry is regarded as one of the challenging topics to teach (Fach *et al*., 2007). Furthermore, it was also indicated that, there is poor performance amongst grade 12 students with regards to the topic (DBE, 2011). Thus, I then suggest that the topic should be introduced in lower grade in South African high school curriculum, so that the science students could develop the necessarily understanding of the concept that is crucial in understanding stoichiometry topic, so that by the time they get to matric level their understanding of the topic is more comprehensive.

In addition to that teachers are said to hold misconceptions in this topic and they pass that to their learners, due to poor content knowledge or lack of pedagogy, and there's lack of qualified physical science teachers (DBE, 2011). With that said it is recommended that stoichiometry should be taught more carefully in order to transform learner's conceptual understanding and perhaps introduce more programs to develop teachers understanding in this topic.

The TSPCK tool that was administered to the pre-service teachers has five knowledge components for transforming learners conceptual understanding in this topic, of which add in the expansion of PCK of the pre-service teachers. So, I suggest that the tool to be used in the development programs for teachers cognitive through the different component.

In this study it was found that component majority of the teacher's difficulties with component 'representation' of TSPCK, unlike conceptual teaching strategy which is theoretical the most difficult component as can have been seen in study by (Mavhunga & Rollnick,2013);(Ndlovu,2014). It need to be made explicit to the pre-service teachers what constitute each components in order to improve their competence in the above mentioned component because by improving the most difficult components it have a positive impact on their TSPCK. And, it would be fascinating know if my findings in this study is isolated with this group or it is general finding within this topic and investigate why teachers have found this component to be the most difficult.

6.8 Reflection on the study

When I look back to the whole study I struggled with the concept of science teacher's Beliefs. I did not understand what it is and its importance in teaching.

Beginning of the study, I had no idea of the amount of knowledge I would gain from this research study. The insight I got from this study is that content is not everything that matters but the correct conceptual framework that the teacher is working with, guided by appropriate learning theory, could help him/her to address learner's misconceptions such that he/she helps learners reconstruct their knowledge base.

6.9 Concluding remark

The aim of this study was to examine the relationship between the quality of PCK in stoichiometry and the Beliefs that science pre-service teachers held at the end of an intervention in their final year of study. Two instruments were used to collect data. The validity of the instruments has been confirmed qualitatively and quantitatively. The purpose of the TSPCK tool was to examine the quality of TSPCK. This was achieved. Different components of TSPCK did show varying depth of responses and the TSPCK rubric was used and it was effective in different components. The second tool was the science teacher's beliefs, and was designed to detect the kinds of Beliefs held by the pre-service science teachers in stoichiometry, using Beliefs map.

Overall, however, the researcher is satisfied that the purposes of this research have been achieved, and that a lot of valuable information and insights have emerged.

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Appendix 1: Ethics: Information Letter

university of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg sa t+27 11 7173414 f+27 11 7173259

Masters Student: Ezra Mashamba
Student No.: 482847
482847@students.wits.ac.za

My name is Ezra Mashamba and I am a fulltime Masters student in the Science Education Division in the School of Education at the University of the Witwatersrand.

I am doing research on **Examining the relationship between teacher science beliefs and the PCK in stoichiometry in final year pre-service teachers.**

My research involves collecting data on the quality of TSPCK in Stoichiometry and teacher science beliefs, then comparing the two for the emerging patterns. This means that I will be looking at your 2015 completed tools in TSPCK in Stoichiometry and science teacher beliefs, when you were in your final year and analyze them. In addition there will be completion of the same tools again to determine the effect of your current activity, either teaching or studying on the pattern emerging from your 2015 data
.
The reason why I have chosen you is because you participated in the intervention targeting the development of TSPCK in Stoichiometry. Would you mind if I invite you to participate in my study as describe above. The main objective on this study is to determine the patterns between the two constructs and ascertain the degree at which learnt TSPCK and science teacher beliefs are retained after the intervention.

Your name and identity will be kept confidential at all times and in all academic writing about the study. Your individual privacy will be maintained in all published and written data resulting from the study.

All research data will be destroyed between 3-5 years after completion of the project.

You will not be advantaged or disadvantaged in any way. Your participation is voluntary, so you can withdraw your permission at any time during this project without any penalty. There are no foreseeable risks in participating and you will not be paid for this study.

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

NAME: Ezra Mashamba
ADDRESS: 16 Broadland; Corner Tyrwhitt & Sturdee Avenue; Rosebank
2196
EMAIL: 482847@students.wits.ac.za

Appendix 2: Ethics: Informed Consent form

Pre-service Teacher's Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: Examining the relationship between teacher science beliefs and the PCK in stoichiometry in final year pre-service teachers at Wits University in the Science Division (physical science)

I, ___________________________ give my consent for the following:

Permission to review/collect documents/artifacts **Circle one**

I agree that my completed TSPCK tools in Stoichiometry from 2015 can be used for this study only. YES/NO

Permission for questionnaire/test

I agree to complete the TSPCK and science teacher beliefs tools for this study. YES/NO

Permission for interview

I agree to be interviewed without audio recording but writing notes during the interview.
YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audio taped, photographed and/or videotape
- All the data collected during this study will be destroyed within 3 years after completion of my project.

Appendix 3: Ethics: Clearance Certificate

Wits School of Education

WITS UNIVERSITY

27 St Andrews Road, Parktown, Johannesburg, 2193 Private Bag 3, Wits 2050, South Africa. Tel: +27 11 717-3064 Fax: +27 11 717-3100 E-mail: enquiries@educ.wits.ac.za Website: www.wits.ac.za

Date: 17 May 2016

Student Number: 482847

Protocol Number: 2016ECE023M

Dear Ezra Mashamba

Application for Ethics Clearance:

Thank you very much for your ethics application. The Ethics Committee in Education of the Faculty of Humanities, acting on behalf of the Senate, has considered your application for ethics clearance for your proposal entitled:

Examining the relationship between teacher science beliefs and the PCK in stoichiometry in final year pre-service teachers

The committee recently met and I am pleased to inform you that **clearance was granted**.

Please use the above protocol number in all correspondence to the relevant research parties (schools, parents, learners etc.) and include it in your research report or project on the title page.

The Protocol Number above should be submitted to the Graduate Studies in Education Committee upon submission of your final research report.

All the best with your research project.

Yours sincerely,

M Mabety

Wits School of Education

011 717-3416

cc Supervisor - Dr Elizabeth Mavhunga

Appendix 4: Permission Letter to Head of Science Division

university of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg sa t+27 11 7173414 f+27 11 7173259

Masters Student: Ezra Mashamba
Student No.: 482847
482847@students.wits.ac.za

11 April 2016

16 Broadland
Corner Tyrwhitt & Sturdee Avenue
Rosebank
2196

A REQUEST FOR PERMISSION TO HEAD OF SCIENCE DIVISION TO CONDUCT RESEARCH STUDY IN THE SCIENCE EDUCATION DIVISION

Dear Professor Oyoo,

My name is Ezra Ndifhedzo Mashamba, and I am MSc (Science Education) student here at Witwatersrand University. I am conducting a study that involves examining the relationship between teacher science beliefs and the Pedagogical Content Knowledge (PCK) in Stoichiometry in final year pre-service teachers. I kindly request your permission to access the archives of tests from the 2015 final chemistry VI methodology class in your Science Education division. This particular class has been chosen because of the nature of its content aiming at developing special teacher knowledge for teaching science called Topic Specific PCK. This project will be conducted under the supervision of Dr. Elizabeth Mavhunga.

The participants will not be advantaged or disadvantaged in any way. Participation of all students is voluntary as well as their granting me permission to look into their 2015 completed tests is voluntary. They can withdraw at any time during this project without any penalty. There are no foreseeable risks in participating and interviewees will not be paid for this study. However, they may benefit from the reflections they might have on the topic.

I hope this request will be considered favourably.

Yours sincerely
Ezra Ndifhedzo Mashamba

Please provide consent, should I meet the required criteria for research:

Sign______________________________ Date____________________________

Appendix 5: Permission Letter to course coordinator

University of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg sa t+27 11 7173414 f+27 11 7173259

Masters Student: Ezra Mashamba
Student No.: 482847
482847@students.wits.ac.za

11 April 2016

16 Broadland
Corner Tyrwhitt & Sturdee Avenue
Rosebank
2196

A REQUEST FOR PERMISSION TO COURSE COORDINATOR TO CONDUCT RESEARCH STUDY IN THE PHYSICAL SCIENCE IV METHODOLOGY CLASS

Dear Dr. Mavhunga,

My name is Ezra Ndifhedzo Mashamba, and I am MSc (Science Education) student here at Witwatersrand University. I am conducting a study that involves examining the relationship between teacher science beliefs and the Pedagogical Content Knowledge (PCK) in stoichiometry in final year pre-service teachers. I kindly request your permission to access the archives of tests from the 2015 final chemistry VI methodology class in your Science Education division. This particular class has been chosen because of the nature of its content aiming at developing special teacher knowledge for teaching science called Topic Specific PCK.

The participants will not be advantaged or disadvantaged in any way. Participation of all students is voluntary as well as their granting me permission to look into their 2015 completed tests is voluntary. They can withdraw at any time during this project without any penalty. There are no foreseeable risks in participating and interviewees will not be paid for this study. However, they may benefit from the reflections they might have on the topic.

I hope this request will be considered favourably.

Yours sincerely
Ezra Ndifhedzo Mashamba

Please provide consent, should I meet the required criteria for research:

Sign______________________________ Date____________________________

Appendix 6: Permission Letter to Head of school

University of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg sa t+27 11 7173414 f+27 11 7173259

Masters Student: Ezra Mashamba
Student No.: 482847
482847@students.wits.ac.za

11 April 2016

16 Broadland
Corner Tyrwhitt & Sturdee Avenue
Rosebank
2196

A REQUEST TO HEAD OF SCHOOL FOR PERMISSION TO CONDUCT RESEARCH IN SCIENCE DIVISION EDUCATION CAMPUS

Dear Professor Brodie,

My name is Ezra Ndifhedzo Mashamba, and I am MSc (Science Education) student here at Witwatersrand University. I am conducting a study that involves examining the relationship between teacher science beliefs and the Pedagogical Content Knowledge (PCK) in stoichiometry in final year pre-service teachers. I kindly request your permission to access the archives of tests from the 2015 final chemistry VI methodology class, a course located in your School of Education. This particular class has been chosen because of the nature of its content aiming at developing special teacher knowledge for teaching science called Topic Specific PCK. This project will be conducted under the supervision of Dr. Elizabeth Mavhunga.

The participants will not be advantaged or disadvantaged in any way. Participation of all students is voluntary as well as their granting me permission to look into their 2015 completed tests is voluntary. They can withdraw at any time during this project without any penalty. There are no foreseeable risks in participating and interviewees will not be paid for this study. However, they may benefit from the reflections they might have on the topic.

I hope this request will be considered favourably.

Yours sincerely
Ezra Ndifhedzo Mashamba

Please provide consent, should I meet the required criteria for research:

Sign______________________________ Date____________________________

Appendix 7: TSPCK tool in Stoichiometry

MASTERS RESEARCH: Protocol number: 2013ECE086M

DEMOGRAPHIC INFORMATION

CODE:	

NAME:		
GENDER	Male	Female
CURRENT SUBJECTS TAUGHT		
NUMBER OF YEARS TEACHING SCIENCE		

QUALIFICATIONS

Degree / Diploma	**Where Obtained**	**Main Subjects**	**Year**

Have you taught stoichiometry?	**YES**		**NO**	

If yes, please indicate the grade and the number of years for each Grade.

Grade	**Number of years**	**Years (e.g. 2008, 2009)**

University of the Witwatersrand | Stoichiometry TSPCK Tool 2

CODE:

CATEGORY A: LEARNER'S PRIOR KNOWLEDGE

1. Before starting the section on reaction stoichiometry you give the learners a diagnostic test. One of the questions in the diagnostic test is reproduced below.

Each cube represents a volume of 22,4 dm^3 at STP. In which of the three pairs of cubes, Set A, Set B or Set C, is there 1 mole in each cube and in which of the three pairs cannot contain 1 mole in each cube?

N_2 (g)	H_2 (g)	O_2 (g)	Hg (ℓ)	SO_2 (g)	S (s)
Set A Cubes		Set B Cubes		Set C cubes	

How would you respond verbally to learners who state that all the cubes contain one mole?

Response A	At standard temperature, or 0°C and standard pressure, or 101,3 kPa one mole of any gas at STP occupies a volume of 22.4 dm^3. This is called the molar volume but it only applies to gases at STP. Hence cubes containing nitrogen gas, hydrogen gas, oxygen gas and sulphur dioxide gas will contain 1 mole. The pair of cubes in Set B contains a liquid in one cube and the pair of cubes in Set C contains a solid in one cube. So, one of the Set C pair of cubes and the Set B pair of cubes contain other substances that are not gases. So Set B and Set C pairs do not contain one mole in each cube.
Response B	That is incorrect. All three pairs of cubes cannot contain one mole of substance. One mole of a gaseous substance occupies a volume of 22.4 dm^3 at STP. So only the cubes of Set A contain one mole. The pairs of cubes in Set B and Set C do not have cubes that all contain one mole of substance since only one of the substances in the cubes of Set B and Set C are gaseous substances at STP.
Response C	It is important to check the phases of the substance. Molar gas volume only applies to substances in the gaseous phase. One mole of any gas at STP occupies 22.4 dm^3. So the cubes containing nitrogen gas, hydrogen gas, oxygen gas and sulphur dioxide gas will contain one mole. There are exactly the same number of gas molecules, approximately 6,02 x 10^{23} particles in these cubes. The other substances in the pairs of cubes, Hg and S, are not in the gaseous phase. You would need to know the masses of mercury and sulphur in order to calculate if the cubes with these substances in Set B and Set C contain one mole of these substances. So, only in Set A is there one mole of substance in each cube in the set.
Response D	None of the above. I have another response which is

CODE:	

Choose your response and indicate the reason(s) for your choice in the space below.

My choice is Response ______

2. After teaching the learners about concentration you give them an exercise to do for homework. In one question you ask learners the following question.

> During a practical lesson you have to make up molar solutions. You are provided with 10 g of sodium chloride, sodium bromide and sodium iodide. You dissolve each of these salts in a 100 ml volumetric flask.
>
> Do these solutions have the same or different molar concentrations? Explain your answer.

How would you respond in writing when giving feedback to the homework exercise to learners who provide the following answers?

The concentration of the three solutions will be the same because you dissolve the same amount of solute in the water.

THE CONCENTRATIONS ARE EQUAL BECAUSE YOU ARE DISSOLVING THE SAME MASS OF THE SALTS IN 100ML OF WATER.

CODE:

Response A	The mass of the salts does not mean that the number of particles is the same. The ions of the different salts have different relative atomic masses and therefore the molar mass of each salt is different and so the concentration of solutions will be different. Referring to the periodic table you can, by inspection, see that sodium chloride has a smaller molar mass than sodium iodide, and would therefore have a greater number of ions. Therefore the amount of salt, measured in moles, will also be different. Remember that just because the mass of each salt is the same the amount of salt, measured in moles will be different. Since concentration is the amount of substance per unit volume, the concentration of the sodium chloride solution will be greater than that of the sodium bromide, which would be greater than that of the sodium iodide. If you add ten grams of the salt to the same volume of solvent you are not adding the same number of ions for the different salts.
Response B	Concentration mathematically is the number of moles per unit volume. You need to calculate the number of moles for each of the three salts. This is done by dividing the mass of the sample by the molar mass of each salt or using the formula $n = m/M$. You need to refer to the periodic table to calculate the molar mass of each salt by adding the atomic mass of each element in the salt. So, firstly calculate the number of moles of each salt in 10 grams of the salt. Once you have calculated the number of moles of each substance then use the formula $c = n/V$ to find the concentration of each solution. The concentration of the solutions will be different.
Response C	You need to understand what concentration is before you answer a question like this. So you were asked to dissolve three different salts in a given volume of water. Then you were asked if the concentration of these three solutions was the same or different. You must remember that concentration mathematically is the number of moles divided by the volume. So you need to workout how many moles of each salt and divide this by the volume of water you dissolved the salts in. The concentration of the three solutions cannot be same even if the mass of these salts is the same and the salts are dissolved in the same volume of water.
Response D	None of the above. I have another response which is

Choose your response and indicate the reason(s) for your choice in the space below.

My choice is Response _______

CODE:

CATEGORY B: CURRICULAR SALIENCY

3. The following questions relate to planning and sequencing of concepts.

3.1. What concepts in stoichiometry at Grade 11 do you believe are the main ideas[1] for understanding by students at the end of the instruction of this topic?

Choose at least three concepts from the provided list and place them in a sequence that depicts the best order of teaching. Provide reasons for both your choice and suggested sequence.

Theoretical yield is the amount of product that is formed when a reaction goes to completion based on the stoichiometry of the reaction.	**Molar ratios** can be used to determine the amount of reactants used or the yield of product formed.
Molar Mass of an element or compound expresses the equivalent relationship between one mole of a substance and its mass in grams.	**Balanced chemical equations** provide the combining ratios of reacting substances and their products in a chemical reaction.
Stoichiometric calculations combine balanced chemical equations and the concept of the mole to calculate the masses of all reactants required and products formed in a chemical reaction.	**Molar Volume** of a gaseous substance expresses the equivalent relationship between one mole of a gas and its volume of 22,4 dm^3 and standard temperature and pressure.
Conservation of mass is a chemical law that allows quantitative relationships to be established in chemical reactions.	**Dilution** is the process of decreasing the concentration of a solution by addition of solvent to a solution.
Concentration is a property of a solution and relates to the number of solute particles per unit volume.	The amount of substance in a given mass or volume can be expressed as a **constant amount of elementary particles.**
Limiting reagent is the reactant that used up in a chemical reaction and determines the amount of product formed.	**The mole** is the SI unit for amount of substance and allows us to connect the macroscopic scale of matter with the microscopic scale of matter and can used to help count elementary particles that make up substances.
Concentrated solutions have more particles per unit volume than **dilute solutions.**	
The **actual yield** of product formed depends on the reagent that limits the amount of the other reactant that reacts.	Gravimetric and volumetric analysis are **quantitative analysis methods** to determine the amount of substance.
Reaction stoichiometry involves the determination of molar ratios of the amount of reactants and products in a chemical reaction through balanced chemical equations.	**Avogadro's number** expresses the equivalent relationship between one mole of a substance and the number of entities it contains. **Avogadro's number has been experimentally** determined to be $6{,}02 \times 10^{23}$ particles
Volume is the amount of space occupied by a sample and from the volume of a gaseous substance the amount of substance can be determined.	**Mass** is the amount of matter contained in a sample and from the mass of a chemical substance the amount of substance can be determined.

[1]**Main ideas are statements describing key understanding that must be learnt in a topic.**

CODE:

	Suggested concepts and sequence	Reasons
1.		
2.		
3.		

CODE:	

3.2. Make a map or a diagram showing how these three ideas link to subordinate concepts.

CODE:	

3.3. What topics/concepts must have been covered in chemistry before you can teach stoichiometry?

List of Topics/Concepts to be taught before Stoichiometry

3.4. Why is it important for learners to learn about stoichiometry? Identify reasons.

CODE:	

CATEGORY C: UNDERSTANDING OF WHAT MAKES TOPIC EASY OR DIFFICULT TO UNDERSTAND

4. What concepts do you find difficult to teach in stoichiometry? Select your choice and provide reason(s) in the table below.

Concept	✓	Why is it difficult for learners to understand?
Amount of substance/mole		
Molar mass		
Molar volume		
Avogadro's number		
Concentration		
Dilution of solutions		
Molar ratios		
Stoichiometric calculations		
Limiting reagent		
Theoretical yield and actual yield		

CODE:

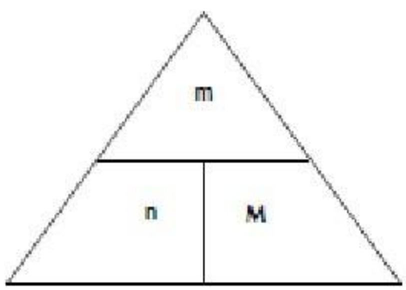
CATEGORY D: REPRESENTATIONS/ANALOGIES/MODELS

5. Below are possible representations for teaching the relationship between mass, mole and number of elementary particles.

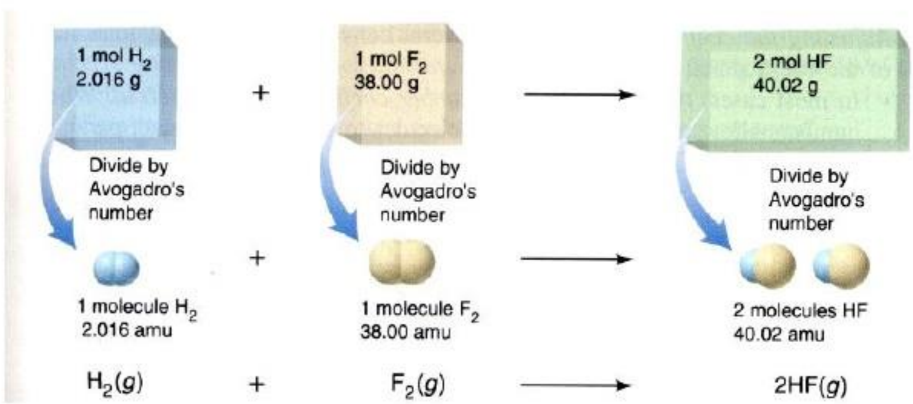
Representation 1

Items	Kind of Set	Number in Set
Socks, dice	Pair	2
Eggs, oranges	Dozen	12
Bottles, cans	Case	24
Brushes, pencils	Gross	144
Sheets of paper	Ream	500
Atoms, molecules	Mole	$6{,}02 \times 10^{23}$

Representation 2



Representation 3



CODE:	

5.1. Complete the table below by providing as many details as possible about each representation.

Representation No.	What I like	What I do not like

CODE:	

5.2. Which representation do you like most?

5.3. How would you use the representation that you like most in a lesson?

CODE:

CATEGORY E: CONCEPTUAL TEACHING STRATEGIES

6. Learners are given the following question in the mid year examination.

About 15% of the world's titanium reserves are found in South Africa. The titanium is a strong, lightweight corrosion resistant metal. It is used in the construction of rockets, aircrafts and jet engines. The titanium is prepared by the reaction of molten magnesium with titanium(IV)chloride at temperatures of approximately 1 000 °C. The reaction is represented by the equation below:

$$TiCl_4(g) + 2Mg(\ell) \rightarrow Ti(s) + 2MgCl_2(\ell)$$

In a certain industrial plant 3 540 kg of titanium chloride was reacted with 1 130 kg of magnesium to produce 894,24 kg of titanium.

Source: Department of Education (2007). Grade 11 Chemistry Paper, November Examination

The learners are asked to determine the limiting reagent of the reaction, giving reasons for their answers. The learners provide the following answers.

Extract 1:	Extract 2:
Titanium (IV) chloride Limiting reagent is the reactant with the least number of moles in the equation	Magnesium This is the reactant present in the least amount according to mass.

Explain how you would assist these learners to move towards the correct answer, explaining what their errors are and highlighting the strategy you will use.

In your response:

(1) Explain why you think your strategy will work.

(2) Indicate what you consider as important in your strategy.

CODE:

THANK YOU. Your assistance is really appreciated in the development of this Instrument.

Appendix 8: TSPCK rubric

TSPCK RUBRIC – SHOWING COMPONENT INTERACTIONS

	Limited(1)	(2) Basic	(3) Developing	Exemplary (4)
Learner Prior Knowledge	• No identification/No acknowledgement/No consideration of student prior knowledge or misconceptions • No attempt to address the misconception.	• Identifies misconception or prior knowledge • Provides standardized definition as a means to counteract the misconception • No evidence of drawing on other TSPCK components.	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Expands and re-phrase explanation using one other component of TSPCK interactively.	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Expands and re-phrases explanation correctly • Confronts misconceptions/confirms accurate understanding drawing on two or more other component of TSPCK interactively.
Curriculum Saliency	• Identified concepts are a mix of Big Ideas and subordinate ideas • Identified pre-concepts are far from topic • Sequencing no value due to mixed concepts • Reasons given are generic - benefit of education.	• Identifies at least 3 Big Ideas • Not all 3 Big ideas subordinate concepts identified • Suggested sequencing has one or two illogical placing of Big Ideas. • Identified pre-concepts are far from the current topic • Reasons given for importance of topic exclude conceptual considerations and show no evidence of drawing on other TSPCK components.	• Identifies at least 3 Big Ideas • Subordinate concepts correctly identified for all Big Ideas • Provides logical sequence • Identifies pre-concepts relevant to the topic • Reasons given for importance of topic include reference to conceptual scaffolding/sequential development draw on one other TSPCK components e.g. what makes topic difficult.	• Identifies at least 3 Big Ideas • Subordinate concepts correctly identified for all Big Ideas with explanatory notes • Provides logical sequence of all three Big Ideas and with logical reasons • Identifies pre-concepts relevant to the current topic and explanatory notes given • Reasons given for importance of topic include conceptual scaffolding with reference to other TSPCK components e.g. Learner Prior Knowledge and what makes topic difficult.
What makes topic difficult	• Identifies broad topics without reasons and specifying the actual sub-concepts that are problematic.	• Identifies specific concepts but provides broad generic reasons such as 'abstract'.	• Identifies specific concepts leading to learner difficulty • Reasons given relate to one other TSPCK components.	• Identifies specific concepts with reasons linking to specific gate keeping concepts and to TSPCK components such as prior knowledge and aspects of curricular saliency.
Representations	• Limited to use of only macroscopic analogies, demos, etc.) representation with no explanation of specific links to the concepts represented	• Use of macroscopic representation (analogies, demos, etc.) and use of scientific symbolic representation without explanatory notes to make the links to the aspects of the concept being explained.	• Use of macroscopic representation and use of scientific symbolic representation with explanatory notes linking the two representation to the aspect(s) of the concept being explained • Use of above representations combination with reference to one other TSPCK components e.g. learner prior knowledge	• Use of macroscopic representation or symbolic representation with sub-microscopic representation to enforce a specific aspect • Explicit link to other components of TSPCK e.g./emphasis of core aspect of CK demonstrated in the representations and learner prior knowledge
Teaching Strategies	• No evidence of acknowledgement of student prior knowledge and misconceptions • Lacks aspects of curriculum saliency • Use of representations limited to macroscopic or symbolic scientific symbolic representation	• Acknowledges student misconceptions verbally with no corresponding confrontation strategy • Lacks aspects of curriculum saliency • Use of macroscopic and symbolic representations with no linking explanatory notes	• Considers confirmation/confrontation of student prior knowledge and/or misconceptions • Considers at least one aspect related to curriculum saliency e.g. sequencing or what not to discuss yet or emphasis of important concepts • Uses at least two different levels of representations to enforce understanding.	• Considers student prior knowledge and evidence of confrontation of misconceptions. • Considers at least two aspects related to curriculum saliency: sequencing, what not to discuss yet, emphasis of important conceptual aspects, etc. • Uses either the macroscopic or symbolic representation with sub-microscopic representation to enforce understanding and may show awareness of learner difficulty.

Appendix 9: Science teacher's beliefs tool

TEACHER BELIEF TOOL - QUESTIONNAIRE

1. How can you increase chances for student learning in your science classroom?

2. Describe how you perceive your role as a science teacher?

3. In a school class, how do you know when your students understand what you are teaching?

4. In a school setting, how do you decide what to teach and what not to teach?

5. How do you decide when to move on to a new topic in your classroom?

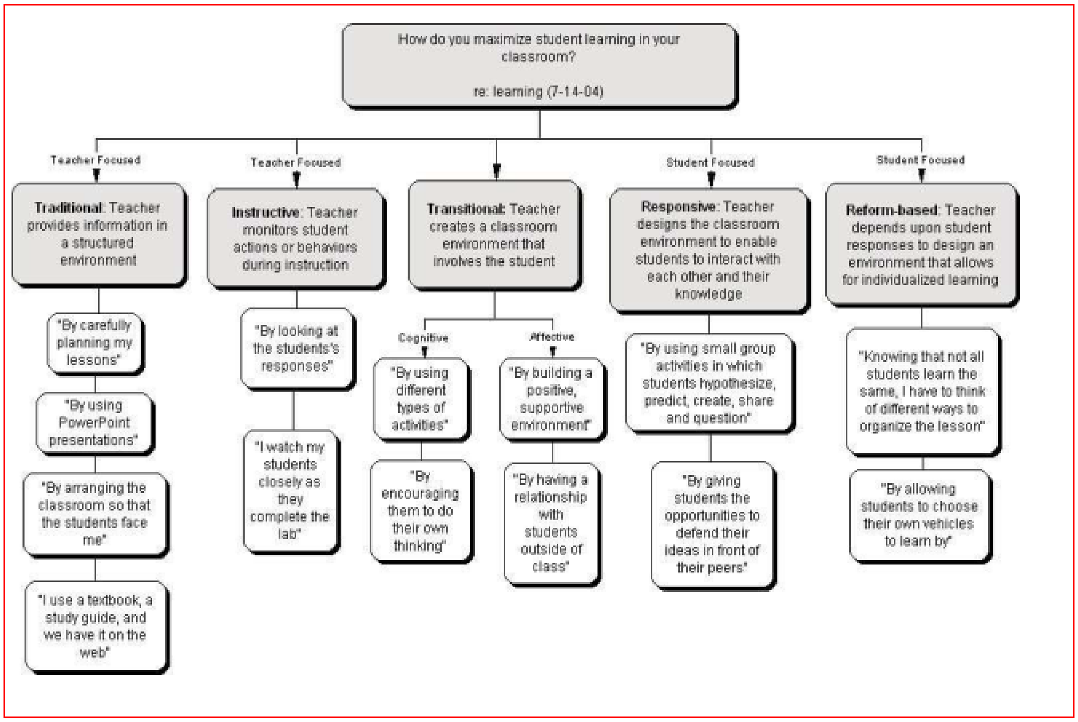
6. How do your students learn science best?

7. How do you know when learning is occurring in your science classroom?

Appendix 10: Science teacher's beliefs map

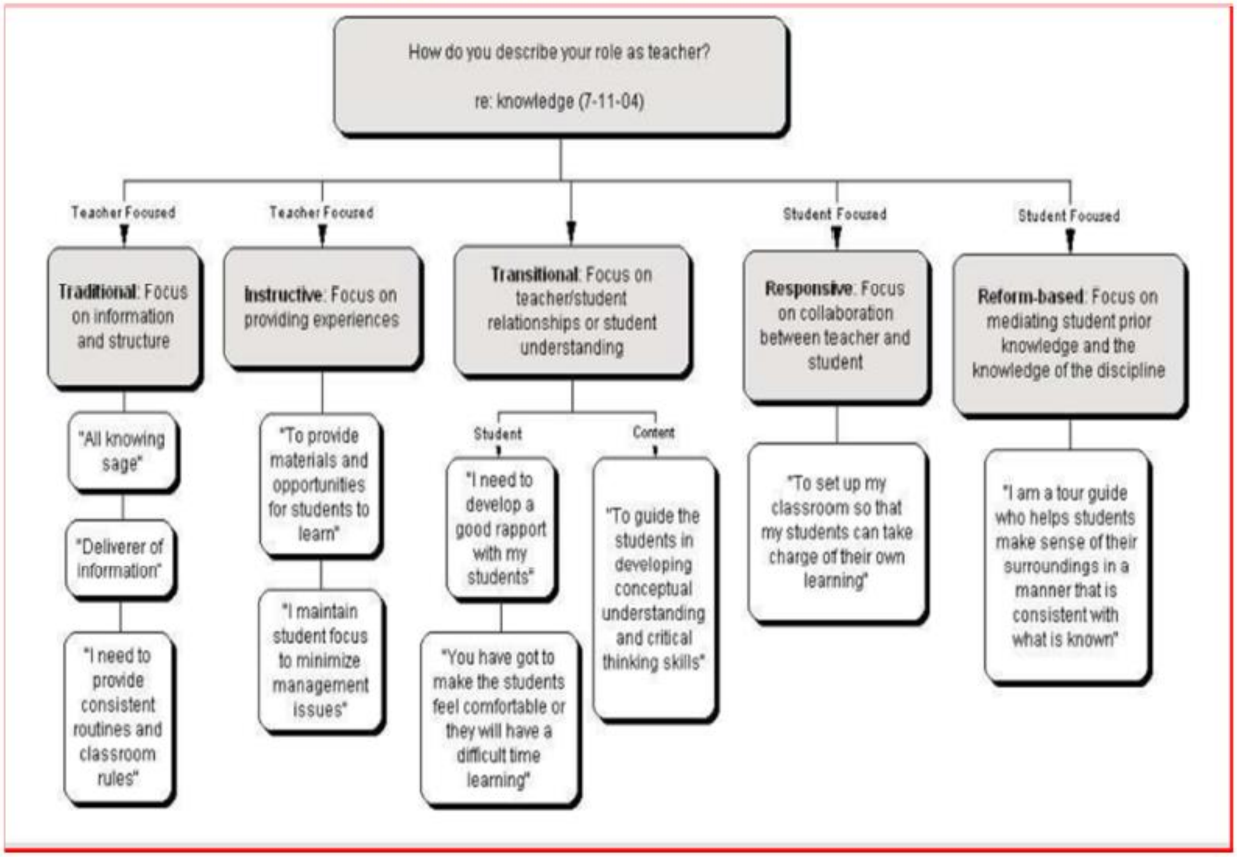
TEACHER SCIENCE BELIEF CODING
Coding Map, extracted from Luft and Roehrig (2007) used to code Question 2 in the modified Belief tool used in this study:

- How can you increase chances for student learning in your science classroom?



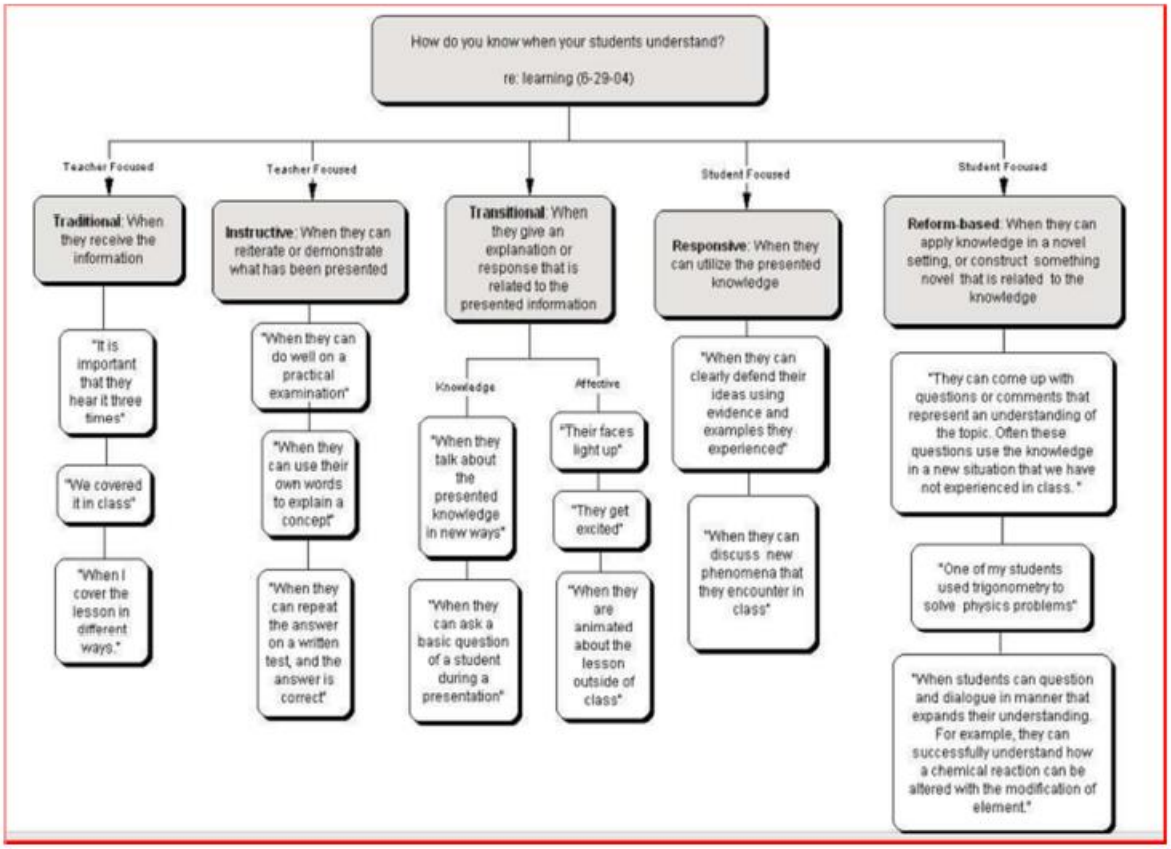
For Question 3 in the modified Belief tool:

- Describe how you perceive your role as a science teacher?



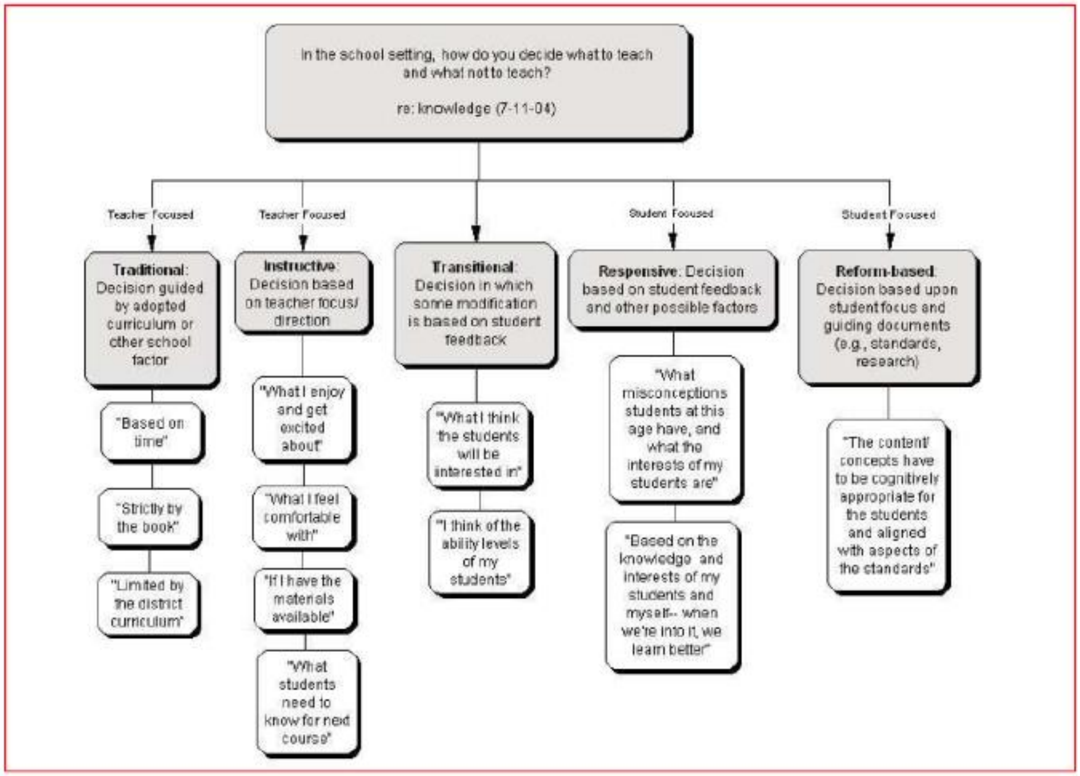
For Question 4 in the modified Belief tool:

- During your school teaching experience, how did you know when your students were understanding?



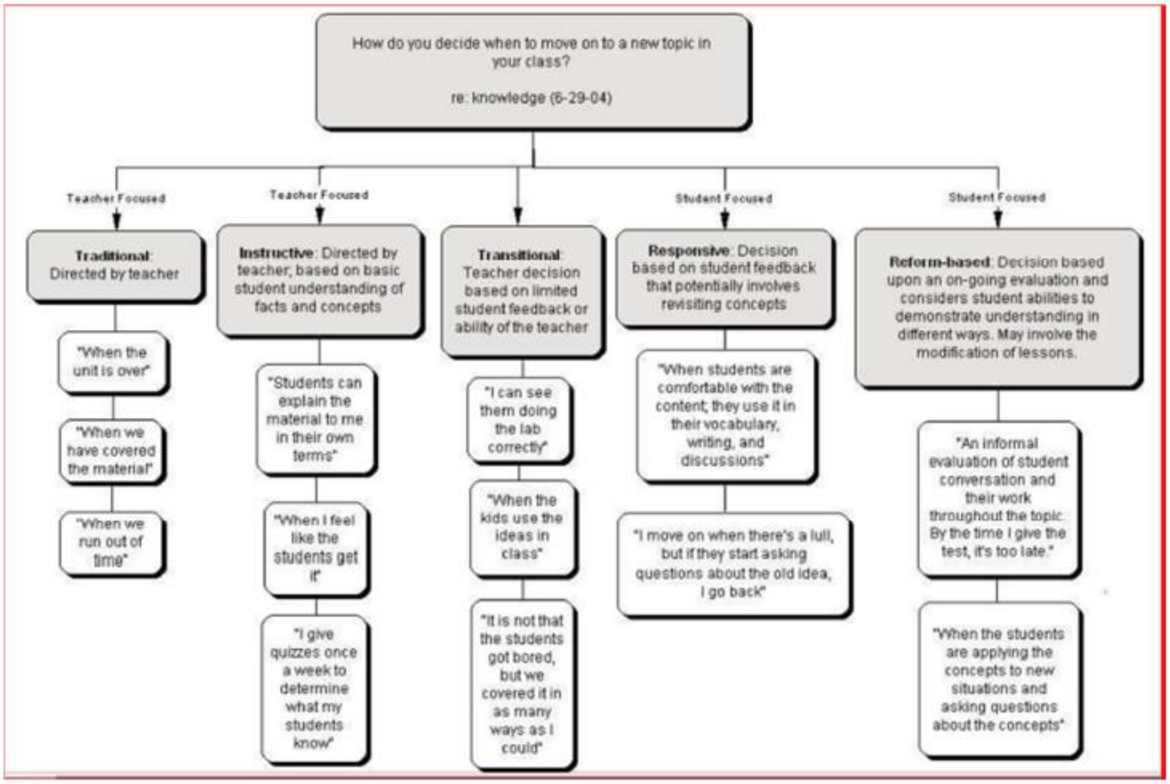
For Question 5 in the modified Belief tool:

- In a school setting, how do you decide what to teach and what not to teach?



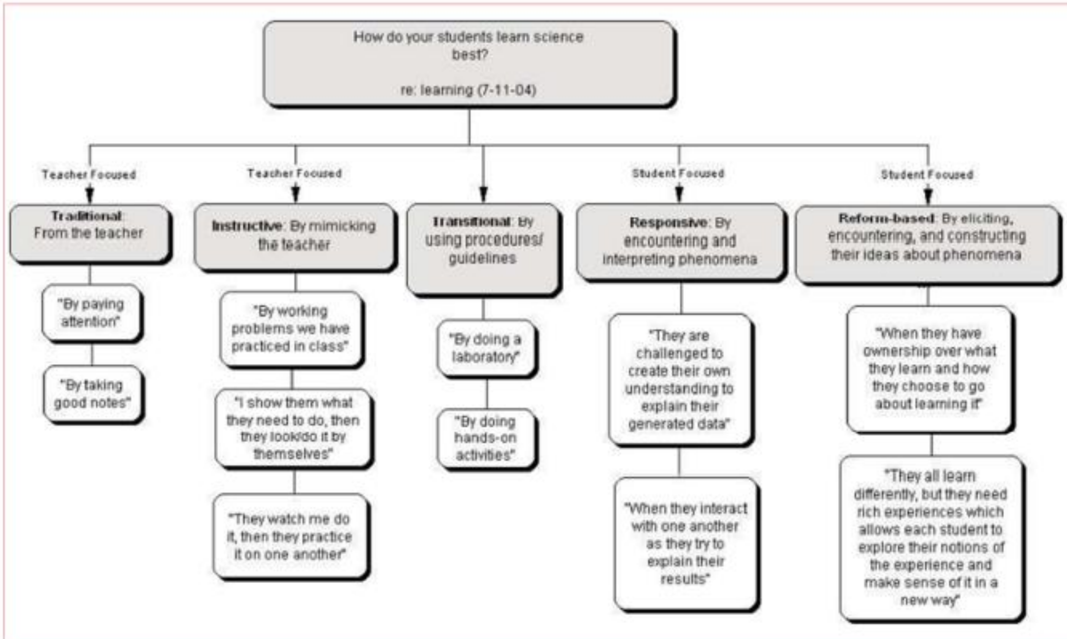
For Question 6 in the modified Belief tool:

- How do you decide when to move on to a new topic in your classroom?



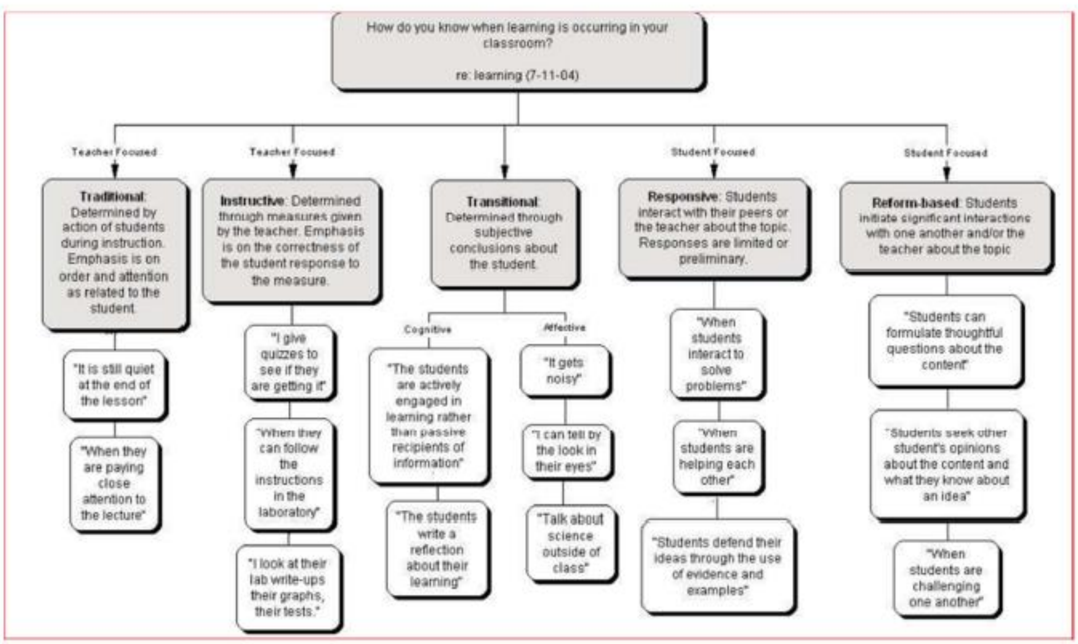
For Question 7 in the modified Belief tool:

- How do your students learn science best?



For Question 8 in the modified Belief tool:

9. How do you know when learning is occurring in your science classroom?



Appendix 11: Interview schedule

1. What do you understand about Topic Specific Pedagogical Content Knowledge

2. How is this understanding different or similar to that you held in your pre-service teacher programme?

3. You have written …… [*taking from the post test*] ….., Now you have written….. [*taking from the third written TSPCK tool after few months of practice*]…. What informed your understanding to change

4. What do you belief teaching science is about? How is this view similar or different from that you held when you were in the pre-service teacher programme?

5. Describe how you perceive your role as a science teacher? How is this view similar or different from that you held when you were in the pre-service teacher programme?