THE INFLUENCE OF EXPERIENCE ON TEACHER TOPIC SPECIFIC PCK (TSPCK) ON CHEMICAL EQUILIBRIUM

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Abstract

Content knowledge (CK) and Topic Specific Pedagogical Content Knowledge (TSPCK) are key components of teacher competence in transforming the science topics. Both CK and TSPCK are mostly developed at the level of pre-service teachers in chemistry topics. However, similar teachers who their CK and TSPCK were developed were not been followed to check their progress of CK and TSPCK in the field of education. Yet, little is known about how experience influences the development of CK and TSPCK within chemistry topics. To address this concern, this study used validated CK and TSPCK instruments to assess teachers CK and TSPCK within the topic of chemical equilibrium. The study involved a group of seven qualified physical science teachers who were once involved in the intervention about TSPCK on a topic chemical equilibrium in 2011. The study intended to find the influence of experience on the quality of teachers' TSPCK. In this study, a group of seven in-service physical science teachers was followed to compare their quality of TSPCK and CK in chemical equilibrium after 8 years of completing their B.Ed. The quality of the teachers' TSPCK was compared between two points, between the time when they were still undergraduate in 2011 and after eight years of experience in the field of education. The study is based on mixed methods research. The data was collected using both CK and TSPCK instruments in chemical equilibrium, as well as interviews. The marking memo was used to score CK tool, and rubric was used as a guideline to score the teachers' responses from the TSPCK tool. The rubric consisted of four levels of competencies, level 1 (limited), level 2 (basic), level 3(developing) and level 4(exemplary). The study identified that teachers' quality of CK and topic-specific PCK was not satisfactory. The following three major reasons were identified from teachers with not well-developed topic-specific PCK, (1) teachers lack experience of teaching grade 12, (2) never taught a topic within a period of 8 years, (3) and lack of attending developmental workshops. Teachers whom their topic-specific PCK developed, taught the topic in grade 12 for the past eight years. These teachers engaged themselves in postgraduate studies and content training. The study revealed that the quality of topic-specific PCK develops with experience 1) **when teachers are teaching that topic**, 2) **when teachers are constantly developed in that topic**, and 3) **when teachers are involved in other courses in science education**. The study can assist both quantitative and qualitative researchers on methods when exploring the influence of the experience on teachers' content knowledge and on the quality of their topic specific PCK in future.

Declaration

I declare that this research report is my own work, and not copied from any other sources unless indicated as a quote. All phrases, sentences and paragraphs taken directly from other sources have been cited and then reference done in full in the reference list. This research report is being submitted for the degree of master's in education (M.Ed.) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other university.

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(Candidate's signature)

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Dedication

To God almighty, He deserves all the Glory.

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Nomenclature

PCK-Pedagogical content knowledge

TSPCK-Topic specific Pedagogical content knowledge

CK-Content Knowledge

1. CHAPTER ONE: INTRODUCTION OF THE STUDY

1.1. Introduction

Chemical equilibrium is a concept that is central to other topics in the teaching of chemistry (Rogers, Huddle, & White, 2000). Its conception is linked to many other topics in chemistry. Widely it is reported that teachers and learners have misconceptions about this concept. It is therefore a course for concern for teachers to develop themselves on this topic to minimize the misconceptions so that they will be able to help learners. Teachers' content knowledge (CK) and pedagogical content knowledge (PCK) need to be developed constantly on this concept. PCK refers to teacher knowledge. It is an essential component of teachers' knowledge base of teaching (Shulman, 1986). CK is the amount of knowledge in the mind of the teacher, it is the knowledge the teacher required to teach (Rollnick & Mavhunga, 2014). Scholars have shown that CK and PCK in science topics can be developed in pre-service teachers (Fernandez, 2014). Mavhunga and Rollnick (2013) also presented that topic-specific pedagogical content knowledge (TSPCK) can be developed when pre-service teachers are subjected to intervention within a topic chemical equilibrium. TSPCK is a construct that is used to change teachers' knowledge of the science topic to be understood by the learners. CK and TSPCK can be developed through shared knowledge from experienced teachers, and again both CK and TSPCK can come from different sources, for example, course work and published journals (Mavhunga, 2019). The major contributing factor to the growth of CK and PCK is the experience (Carlson & Daehler, 2019).

1.2 Background and Context of the study

Qualified physical science teachers from University of Witwatersrand school of education in South Africa participated in this study. The study focused only on cohort of physical science teachers who were exposed to a methodology course in the year 2011 aiming to develop their TSPCK in the topic chemical equilibrium. This study took place in 2019 were all teachers were qualified and they had eight years of teaching experience. as a challenge of lack of educators in South African schools some of these teachers were teaching natural science in grade 8 and 9, and mathematics in the grade 10 to 12, and only two teachers were specifically teaching physical science in grade 12. In South Africa Natural science that is taught in grade 8 and 9 includes physics, chemistry, life science and geography. The curriculum in physical science is divided into physics and chemistry.

In high school, college, and university curriculum the topic of chemical equilibrium is one of the main topics in chemistry (Abell, Hanuscin, Lee, Gagnon & Rogers, 2009). The topic is the most abstract, and there are many difficulties associated with it, e.g. procedural and conceptual difficulties (Raviolo & Garritz, 2008). These difficulties pose many challenges to many teachers and learners (Rogers, Huddle & White, 2000). Its abstractness is perpetuated by dynamic nature, differentiation between equilibrium and non-equilibrium circumstances, Le-Chatelier's principle mental manipulation, and other energetic considerations (Niaz, 2008; Tyson, Treagust & Bucat, 1999), and analogies in teaching (Raviolo & Garritz, 2008). My own experiences of teaching chemical equilibrium in grade 12 and my observations of other teachers support these findings. Many learners at secondary school experience difficulties in understanding the topic. As a result, teachers should be trained thoroughly during their undergraduate studies to understand how to teach the topic, so that they can help learners. Many studies adapted the pedagogical knowledge (PCK) construct in chemistry education to develop science teachers. To develop teachers' PCK, Lederman, Gess-Newsome & Latz (1994) asserted that teachers are required to gain experiences in teaching practice when teaching the topics.

1.3 Purpose of the study

Every teacher continues to learn with experience in teaching. Teachers improve content knowledge and new ways of teaching as they plan, teach, and reflect on their lessons. Also, they learn when they discuss with other teachers. There are many other things teachers experience in the field of education that might contribute to their development of CK and TSPCK. Teachers' CK and TSPCK grow when are engaging in the preparation of lesson plans, reflecting on their enacted lessons, attending teacher developmental programs, study postgraduate courses, and interacting with other colleagues. Teachers experiences play a major role in developing teachers' knowledge. Despite the experience or number of years teacher might have in the field of teaching, a teacher continues to learn, however, there are factors that might hinder the development of teacher's knowledge, for example, lack of teacher support, teacher's lack of interest in teaching and poor school environment. The objective of this study was to establish how the experience influences the quality of teachers' CK and TSPCK, and what are the teachers' perceived reasons for change or lack of change in the quality of TSPCK.

1.4 Rationale

Many studies are conducted on the undergraduate level with pre-service teachers focusing on the development of CK and TSPCK in chemistry topics. Research work has been done on a study whereby same teachers are followed to check on how far their CK and TSPCK has developed with experience. So, there is a need to follow teachers in the education field in order to check how the experience influenced the quality of teachers' CK and TSPCK. Basically, in this study, I wish to find out to what extend teachers' CK and TSPCK has developed in the field of education in the topic of chemical equilibrium after eight years of experience. Understanding how teachers' knowledge for teaching chemical equilibrium developed over time, and how experience played a role in this development, can potentially add value to the design of teacher developmental programmes to provide support to teachers on this topic. Also, this study is hoped for adding value to the existing literature on how experience impacts on teachers' knowledge at a topic level.

1.5 Problem statement of the study

Many teachers in South Africa find chemical equilibrium challenging to teach regardless of having teaching experience. Their content knowledge about the topic of chemical equilibrium is not adequate, and teachers have many misconceptions. Teachers require good content knowledge to be able to teach a good lesson. Consequently, good PCK is required to transform content knowledge. However, it takes time to develop PCK (Grossman, 1990). In South Africa, there are many challenges faced by the teachers upon completion of Bachelor of Education degrees. One of the challenges is that many teachers in South African schools do not teach the subjects they majored with at Universities or Colleges. Some are trained to teach at FET phase subjects, but they found themselves teaching at primary schools because of the scarcity of teaching jobs in South Africa. So, that poses a challenge to them, because there are possibilities that their CK and PCK on the subject they majored with will not develop. CK and PCK of the subject matter knowledge develop with experience if teachers are teaching that subject matter knowledge (Grossman, 1990). Another challenge that I observed during my teaching experience in Limpopo and Gauteng province is that teachers in Limpopo province especially in rural places are less privileged because many schools lack resources, and the teachers lack developmental support. In Gauteng province, teachers are attending developmental programmes more often, and they gather in content training meetings constantly. The focus on these developmental workshops was to develop teachers' content knowledge and teaching strategies of teaching the science topics. Their knowledge about teaching science topics it will continue to grow as they engage themselves in these workshops, and it will grow with the experience as they teach (Veal and MaKinster, 1999). Furthermore, the teacher's knowledge grows when they plan lessons and engage with other colleagues. In summary, despite the support or lack of support teachers are exposed to, some teachers do not do the planning of the lessons, thus results in ineffective teaching. In rural provinces, there is a lack of content training workshops. Some teachers teach subjects that they are not qualified for, because of the lack of teaching jobs that are relevant to their major subjects. The notion that teachers' PCK grows with experience in teaching, whereas there are teachers who still face challenges encouraged the undertaking of this research.

1.6 Research questions

The central question of this study is: What is the influence of the experience on the quality of teachers' TSPCK in teaching chemical equilibrium? To address the above central question the next two questions will be answered :

1. What is the quality of teachers CK and TSPCK in teaching chemical equilibrium after 8 years of completing B.Ed.?
2. What are the physical science teachers' perceived reasons for the change or lack of change in the quality of TSPCK?

1.7 Research structure

Chapter one presents the introduction to the study. The following were included: the background of the study, purpose, rationale, problem statement of the study and research questions for the study.

Chapter two presents the literature reviews, this includes the literature about PCK, CK, TSPCK and some literature related to teaching and learning chemical equilibrium.

Chapter three provides the research methodology of the study. This includes the sampling of participants, discussion of research instruments, and the processes of data collection, processes of data analysis as well as the issues around validity and reliability. Finally, this chapter addresses issues of ethical considerations of the study.

Chapter four presents the analysis of the results of the study. This includes the results, analysis, and interpretation of the CK and TSPCK tests scores. This chapter presents the Quantitative and qualitative analysis of the data.

Chapter five presents the analysis of the qualitative interviews data. It includes findings from the interview transcripts.

2. CHAPTER TWO: LITERATURE REVIEW

In the previous chapter introduction of the study was presented, the rationale, purpose, and research questions that guided the study. This chapter presents the literature on teacher knowledge, I start by presenting pedagogical content knowledge with the consideration of different PCK models. Secondly, the discussion is based on the development of PCK in the field of education. Thirdly, I will give an overview of teaching and learning the topic chemical equilibrium, and finally, the TSPCK will be discussed under the adopted theoretical framework.

2.1 Introduction

Science teachers' role is to assist learners to comprehend science content knowledge. So, for teachers to achieve their role, teaching and learning process must be effective. For effective teaching and learning in science, teachers use their special knowledge termed pedagogical content knowledge (PCK) (Shulman, 1986). The term pedagogical content knowledge is a form of knowledge used by teachers in teaching to transform content knowledge into teachable form. Along with PCK, he included other knowledge bases such as content knowledge, curriculum knowledge, learners and their characteristics, educational contexts, and educational purpose (Shulman, 1987). PCK involves the presentation and formulation of content knowledge (CK), pedagogical strategies, and knowledge of what makes content difficult or easy to learn. In fact, PCK is important in teaching chemistry topics like chemical equilibrium because it is a concept that is perceived by teachers to be difficult to teach and is causing many misconceptions amongst learners. The main characteristic of what is required to teach a science topic is the teacher's competence to convert content knowledge of the subject in a way that is easily available to learners. To be able to perform such a transformation, teachers must know things about the subject matter content that are related to its ability to be teachable (Geddis, Onslow, Beynon, & Oesch, 1993). Teachers should understand the knowledge components that they have to use to transform a topic, namely; "(i) Learners' Prior Knowledge, (ii) Curricular Saliency, (iii) What is difficult to teach, (iv) Representations, and (v) Conceptual teaching strategies" (Rollnick & Mavhunga, 2014). These knowledge components and how they link with each other are shown on the model of topic-specific PCK (TSPCK) developed by Mavhunga and Rollnick. The model of TSPCK was selected to be used in this study as the conceptual framework in looking at how teachers' quality of TSPCK within a topic has changed over time.

2.2 Teachers' Pedagogical Content Knowledge and PCK models

Shulman (1986) presented the concept of PCK, which he argued is basic knowledge that every science teacher should have. PCK involves transformations of content knowledge into a form that learners can understand. It is the knowledge that takes account of comprehension of what makes the learning of topics difficult or easy (Shulman,1986). Many scholars perceived the notion of PCK differently. Kind (2009) examined numerous models of the PCK construct for a teacher in science education. Kind (2009) organized the PCK models into two groups, namely "transformative" and "integrative". A transformative model describes PCK as a result "of new knowledge from the transformation of CK, pedagogical and contextual knowledge for the purposes of instructing learners" (Kind, 2009, p. 180). Transformative model is applied to transform subject matter knowledge (Kind, 2009), meaning to use subject matter knowledge in generating PCK. However, in the integrative model, PCK was seen as a combination of teachers' subject matter knowledge (SMK), knowledge of learners, knowledge of setting, and pedagogical knowledge (PK) (Cochran, De-Ruiter, and King, 1993). These knowledge circles intersection and integrate to formulate teachers' PCK. The integrative types of models have teachers' CK as sub-level of knowledge within their PCK-model (Kind, 2009). Whereas Cochran et al. (1993) presented another term for PCK in their model, a PCKg. This term PCKg highlights characteristic of PCK that means it can constantly grow, there are four different ways in which PCK grows, which will be discussed later. Nezvalová (2011) divided PCK into 4 stages which are PCK-general, subject-specific PCK, domain-specific PCK, and topic-specific PCK. General PCK involves having a general understanding of ways of teaching; subject-specific PCK involves knowledge for teaching that is specific to a subject (for example, teaching physical science). The third stage of PCK which is domain-specific will involve knowledge for teaching a chemistry section or physics section of physical science whilst topic-specific PCK talks about knowledge for teaching a specific topic such as chemical equilibrium, acids and bases, etc (Nezvalová, 2011).

Different conceptualizations of PCK was considered and debated in the PCK summit in 2012. Scholars reached a consensus about the new PCK model called, 'PCK Summit Consensus Model' (Gess-Newsome, 2015, p. 31). PCK was defined as an individual characteristic of a teacher, reflected both teacher's knowledge in planning and practice. Equally, it is the teacher's knowledge of reasoning, planning for, and performance of teaching a certain science topic in a certain approach for a certain reason to specific learners for heightened learners' outcomes (Gess-Newsome, 2015). PCK consensus model (see figure below), at the top the model displays the teacher professional knowledge bases (TPKB) for teaching (Gess-Newsome, 2015). At this stage, the model shows the general knowledge base. This is the knowledge that a professionally qualified teacher must have, and this could be common for every qualified teacher. The model at this stage shows that every professional teacher must have this combination of this knowledge bases: knowledge about assessment, knowledge about ways of teaching (pedagogical knowledge), knowledge about learners, and curricular knowledge (Gess-Newsome, 2015).

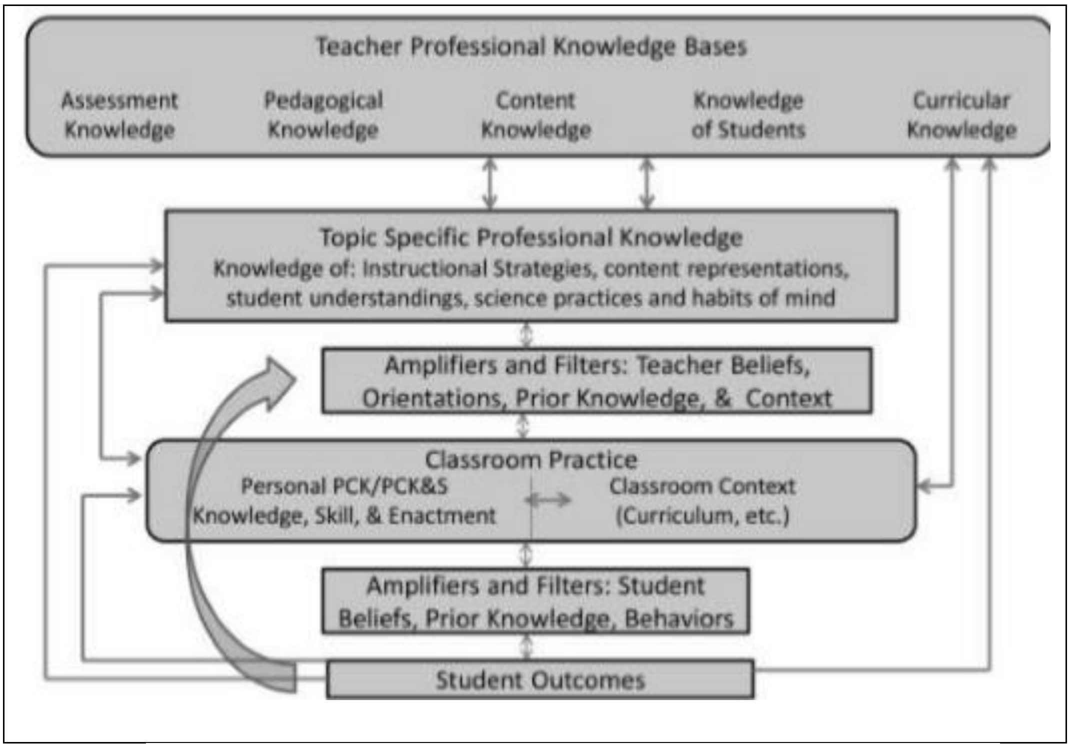


Figure 2. 1: **PCK Summit Consensus Model (Gess-Newsome, 2015, p. 31).**

Considering the consensus model above on the second stage termed "Topic Specific Professional Knowledge" (TSPK), all aspects that are required to teach a topic are embedded on this stage. TSPK concerns specific topics and the development of learners (Gess-Newsome, 2015). The knowledge contained by this category would include: "knowledge of institutional strategies, content representations, student understandings, science practices and habits of minds" (Gess-Newsome, 2015, p.31). The emphasis placed by the model is specifically on a topic, it converges the general PCK (TPKB) to topic-specific professional knowledge (TSPK) (Kind, 2015). Again, the knowledge domains from the first stage (generic TPKB) are connected to the second stage (TSPK). This shows that the general PCK (e.g. content knowledge) is significant to topic-specific professional knowledge. And the second stage is connected to the "classroom practice" and "student outcomes" (see the arrows on the figure above). This is an indication that there is a link between PCK in planning and PCK in practice. Also, the TSPCK framework that is chosen to be a theoretical framework for this study falls well on the second stage on the consensus PCK model, this framework will be discussed later in this chapter. TSPCK is defined as the understanding and application components on content, these components are specific to the transformation of the content of a topic (Mavhunga, 2012). Meaning, having well topic-specific PCK, and its components might bring about better classroom teaching, and expected student outcomes.

The Refined Consensus Model (2019) introduces the lowest grain size of PCK which is concept specific PCK. Also included in this RCM are three realms of PCK which are collective-PCK (cPCK), personal-PCK (pPCK) and enacted-PCK (ePCK) as reflected in Figure 2.2 below.

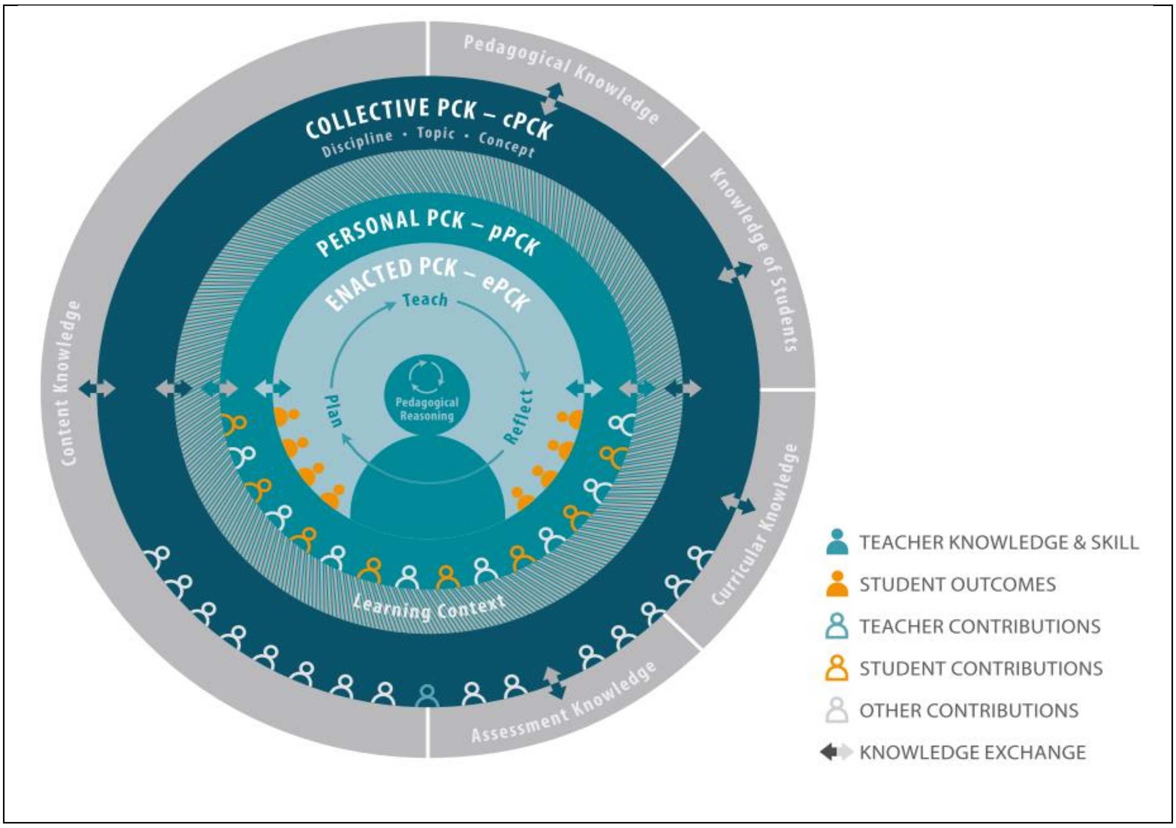


Figure 2. 2: **Representation of Refined Consensus Model of PCK (Carlson & Daehler, 2019).**

Carlson and Daehler (2019) describe three realms of PCK respectively as follows:

> *"**collective PCK**…the specialized expert knowledge held by multiple teachers in a field, **personal PCK** is the personalized expert knowledge held by an individual teacher in science, and **enacted PCK** is the unique subset of knowledge that a teacher draws on*

to engage in pedagogical reasoning during the planning of, teaching of, and reflecting on a lesson". (p.82)

The first pPCK is drawn from the cPCK, as Mavhunga (2019) argued that both pre-service and in-service teachers could draw first on and develops their knowledge from a combined expert about their PCK. She further argued that this shared expert knowledge which is referred to pPCK may arise from various sources like coursework, journals or publications and structured programs are focusing on collective-PCK for teaching science topics (Mavhunga, 2019). In the same breath, personal PCK also influenced by the learning context, can be school or classroom in which teaching and learning is taking place. Over the period, this pPCK is developing when teachers are engaged in formal education programmes and professional sharing of content. More importantly, in science teaching, teaching experiences can mould, reforms and develop the teacher's pPCK. As a result, teacher's pPCK becomes more specialised knowledge for the transformation of science topics to learners. Different teachers develop different specialised knowledge and skills for teaching science because teachers are exposed to different learning experiences and classroom situations or learners. However, even if teachers are exposed to similar experiences, teacher education programmes or teaching the same learners, still they will have developed varied pPCK. The model in figure above provides the opportunity to deliberate about how to offer support teacher development over the teaching career from the level of pre-service teachers to master teachers "by considering the role of experience, learners, and colleagues in the development of PCK for teaching science at the individual level" (Carlson & Daehler, 2019, p.92). Therefore, this study is intended to see the influence of the experience on the quality of teachers' TSPCK in teaching chemical equilibrium.

2.3 Teachers' Content Knowledge

Shulman (1987) defined "content knowledge as the amount and organization of knowledge per se in the mind of the teacher" (p.9). Thus, CK is viewed to be self-explanatory (Rollnick & Mavhunga, 2014). This is the knowledge the teacher required to teach. Any teacher must have good content knowledge to help learners to understand the concepts better. Teachers use their PCK to transform their content knowledge so that it is accessible to the learners (Shulman, 1987). Consequently, content knowledge is a pre-requisite for PCK (Mavhunga & Rollnick, 2013), this means teachers required good content knowledge for them to have good PCK. So, it is important for teachers to master content knowledge of the subject they teach. Shulman (1986) argued subject content knowledge covers central facts, concepts, theories, and procedures, also the knowledge of explanatory frameworks that organize and connect ideas together.

According to Shulman content knowledge differs from one subject matter to the other, also the methods of deliberating the content structure of knowledge differ. Furthermore, Shulman (1986) argued that to think appropriately about CK requires one to have knowledge beyond the concepts of a subject matter knowledge. An understanding of subject matter knowledge and its structures is required (Shulman, 1986). Subject matter knowledge involves both science content knowledge and knowledge for teaching. Knowledge for teaching is said to be ways of teaching a science topic, whereas CK is said to be the amount of unique teacher knowledge about the content. Thus, the amount of knowledge about the topic that the teacher can transform using different teaching strategies and representations can be referred to. So as a science teacher it is crucial to have a sound SMK in order to have a good PCK.

It was noted by Rollnick and Mavhunga (2015) that teachers should have the ability to connect SMK/CK and PCK together, as this forms a better way to transform any topic. Thus, good, or sound CK/SMK is a pre-requisite for good PCK. However, to have good CK/SMK doesn't naturally mean the teacher has the competency to transform content knowledge to pupils (Kind, 2009). Teachers' competences to transform CK it comes with how teachers draw together and integrate knowledge components for the purpose of designing a meaningful conceptual teaching strategy for the topic. According to Park and Chen (2012), there should be a high link between different knowledge components of topic-specific PCK and its interaction. These knowledge components are part of the theoretical framework in this study and are discussed later in this chapter.

2.4 Teachers' experience and development of knowledge for teaching

Pedagogical content knowledge is "the knowledge that teachers had, and it develops over time, and through experience" (Laughran, Berry & Mulhall, 2006, p.9). Teachers' PCK develops when they are engaging with many learning opportunities, these opportunities could be made implicit or explicit (Grossman, 1990). Explicit learning opportunities could be teacher academic education. In the first phase of these learning opportunities are structured university courses that engage the pre-service teachers, and, which the second phase during in-service practices (Nolet, 2015). Explicit learning opportunities in in-service teacher education involves formal developmental programs such as attending content training and workshops. However, implicit learning refers to non-formal learning experiences which involve collaborating with colleagues and observing someone teaching.

Grossman (1990) pointed three possible sources that are contributing to the development of CK and PCK to enhance teachers' expert competence, namely: teachers' own learning experiences, teacher education, and developmental programs and teaching experiences. These three sources are recognized in RCM (see section 2.1.2 above), on the other hand, the model extends more on ways on how CK and PCK can be developed throughout from novice teacher to expert teacher (Carlson & Daehler, 2019). They develop at a collective or individual level. As a collective and continues, PCK develops from the expert knowledge shared by teachers in a group. That knowledge and action are used to inform teaching (Schneider, 2019). At the individual level teachers develop by drawing on their daily planning of lessons, teaching lessons, and lesson reflections (Sorge, Neumann & Stender, 2019). More importantly, teaching experience supported by well-constructed teacher education programs and teachers' reflections is vital for developing full-bodied PCK in teachers.

Geddis, Onslow, Beynon, Oesch, (1993) conducted the study on the transformation of content knowledge within the topic "isotope". They compared the actual teaching of an experienced teacher to a pre-service teacher and found that the experienced teacher was able to implement teaching strategies skilfully and managed to deal with learners' difficulties than a pre-service teacher. Schmelzing, Van Driel, Juttner, Brandenbusch, Sandmann and Neuhaus (2013) found similar findings when conducted the study with 93 pre-service teachers and in-service biology teachers in teacher education research that focused on teachers PCK and effectiveness of teaching as well as learners' achievement gains within a topic of blood and the human cardiovascular.

PCK at the level of pre-service teachers showed to be developed in teacher education modules including systematic student-tutor intervention (Mavhunga & Rollnick, 2013, Kratz & Schaal, 2015; Morrison & Luttenegger, 2015). The implementation of PCK in teacher education programmes should be defined and packaged at the topic level (Mavhunga & Rollnick, 2013). TSPCK construct has promised for producing teacher graduates who are exposed to such reasoning at least in a selection of core science topics. The construct can also be implemented "in teaching practice, and the professional support programmes may be structured to develop PCK in one topic at a time, rather than placing emphasis overwhelmingly at the discipline level" (Mavhunga & Rollnick, 2013, p.124).

In summary, skills, and competence of transformation of CK of a teacher reflect their own teaching and learning experiences, as well as how others contributed, including structured courses. Their transformation can be seen when they plan or teach a lesson. Thus, this study intended to find out the influence of teachers' experiences on the quality of TSPCK in topic chemical equilibrium. The topic of chemical equilibrium is chosen in this study because it is said to be central to teach other topics and abstract concepts in chemistry. Both teachers and learners develop numerous misconceptions about this topic (Abell et al., 2009). The influence of experience on teachers' quality of TSPCK needs to be investigated regarding the concept, results must be presented, so that teachers can be developed if there is a need, to minimize the misconceptions when teaching the topic.

2.5 Teaching and Learning about chemical equilibrium

Chemical equilibrium is a topic that many learners fail to comprehend. It is an abstract concept (Raviolo & Garritz, 2009), and there are many misconceptions associated with it, as a result, those misconceptions cause difficulties for teachers to transform the topic to learners. The misconceptions that are related to chemical equilibrium were revealed in the study conducted in Western Australia with 17 years aged learners. The study reported four major misconceptions within the topic, they were:1) the forward reaction rate increases with time from the moment reactants are mixed until the equilibrium is reached; 2) when a change in condition is made to the system at equilibrium, the reaction rate of the favoured reaction goes up, and the reaction rate of the unfavoured decreases; 3) learners' prior knowledge of reactions that reach completion showed to have impacted their understanding of equilibrium reactions, many learners failed to differentiate between the reactions that reach completion and reversible reaction; and 4) learners failed to conceptualize the mathematics relationship occurred between the concentrations of the reactants and products at equilibrium (Hackling & Garnett, 1985).

Other study reported that chemical equilibrium is abstract in nature, it was reported that the most abstract concepts linked to a topic are "its dynamic nature, the distinction between equilibrium and non- equilibrium situations, the mental manipulation of Le Chatelier's principle, and some energetic considerations" (Raviolo & Garritz, 2009, p.5). Also, it is the concept that involves an understanding of the chemical reactions in different levels, for instance, the way reaction takes place at the sub-microscopic level (unobserved). So, to impart the concept, models and analogies are used to help learners to comprehend. According to Gilbert and Boulter (2012) models are illustrations of conceptions, objects, events, systems, and are used to explain macroscopic nature in terms of the sub-microscopic conformation of matter. Analogies are mental models that make unfamiliar or abstract information easily accessible or to think about with what is existing in learners' mind or familiar with, such that the unfamiliar is linked to familiar. However, if these models and analogies are not well used, they can create difficulties for learners to conceptualize the subject matter. It is important for the teacher to not only know the content but ways of teaching it effectively for the learners to conceptualize. A possible solution might be that teachers should do in-depth planning, relevant formative assessment, and more often reflection. By doing so, it will promote their explanations which can help learners to perceive the use of analogies (Harrison & De Jong, 2005). However, in-depth planning requires the teachers to have a sound CK and competence to transform the topic.

2.6 Theoretical Framework: Topic-specific-PCK

In this study, Topic-specific-PCK model by Mavhunga (2012) is chosen as the theoretical framework (see figure 2.2 below). This model focuses on the transformation of content knowledge or topic. It is the model that teachers can use to change their own knowledge of the science topic to be understood by the learners. TSPCK model was developed following from the work done by Davidowitz and Rollnick (2011). They listed the four general teacher knowledge domains, namely: knowledge of context, knowledge of learners, subject matter knowledge and pedagogical knowledge. These knowledge domains generalise the knowledge from which a teacher draws to inform PCK (Davidowitz & Rollnick, 2011). These knowledge domains and how they link with each other are shown on the model of TSPCK developed by Mavhunga and Rollnick. TSPCK model as shown in figure 2.2 below contains five components that the teachers need to understand and apply to content. Five components are explained below:

Learners' Prior Knowledge

This component covers misconceptions that are common, or teachers' understanding of learners' preconceptions and alternative ideas about the topic being taught (Mavhunga, 2012). These alternative ideas could be those that learners come to a class of which is the knowledge that may arise from everyday lives, or from previous grades or personal experience (Lane, 2015). These preconceptions influence how learners learn and as well as how teachers teach the topic. Therefore, teachers should first establish a way of finding out about learners' prior knowledge before they can teach any lesson (Lane, 2015). That could help a teacher to come up with possible teaching strategies to address learners' pre-ideas, thus will enhance learners understanding

Curricular Saliency

This component of TSPCK covers the knowledge of the teacher about the importance of the topics in relation to the whole curriculum, which allows teachers to be able to select main concepts and big ideas and keeps less important facts at minimal (Park & Oliver, 2008b). Similarly, Magnusson et al. (1999) consider this component as the knowledge that the teachers required to set goals and objectives for the learners, their understanding of selection of teaching materials and resources also their knowledge about the depth and width of the syllabus. This component place stresses on teachers' knowledge for categorising big ideas in a topic, placing concepts/ideas within a topic in order; knowing pre-concepts that are important before teaching the topic, and also topics to be left out while teaching (Rollnick & Mavhunga, 2014).

Representations

Representation is one of the components of TSPCK covering the knowledge of various levels (Macroscopic, Symbolic, and Microscopic) and explanations of the concepts in a topic (Kleickmann et al. 2013). There are four levels of representations reported widely namely, macro, micro, sub-micro, and symbolic representations. Largely these components play important roles in scaffolding learners' learning. Gilbert and Boulter (2000) considered representations as forms of models used to represent ideas, events, objects, processes, or systems. Models are used to explain macroscopic forms, also representations of ideas, objects, events, processes or systems (Gilbert and Boulter, 2000), and are particularly useful when teachers explain macroscopic nature in terms of the sub-microscopic composition of matter (Coll et al., 2005).

What is difficult to teach

This component of TSPCK covers teachers' knowledge about gatekeeping concepts that are problematic, and the ability to identify areas that are challenging in a topic (Mavhunga, 2012). It could be the concepts or topics in science that are difficult to teach, or that are difficult for learners to learn. As well as differences in learners' styles to learning as they relate to the growth of knowledge within specific science topic areas (Magnusson et al., 1999)

Conceptual teaching strategies

Conceptual teaching strategies refer to teachers' knowledge of specific strategies, containing activities and representations for helping learners to grasp a science topic (Magnusson et al.,1999). This component includes recommended strategies for misconceptions, it involves the use of more than one theory/principle to confirm the prediction and use of representations.

The model of TSPCK as shown in figure 2.2 below was selected to be used in this study as the theoretical framework. Mavhunga and Rollnick (2013) argued that the reasoning of content through the five components of the model produces knowledge for teaching that is specific to the topic. The five components discussed above help the teacher to convert CK of the topic.

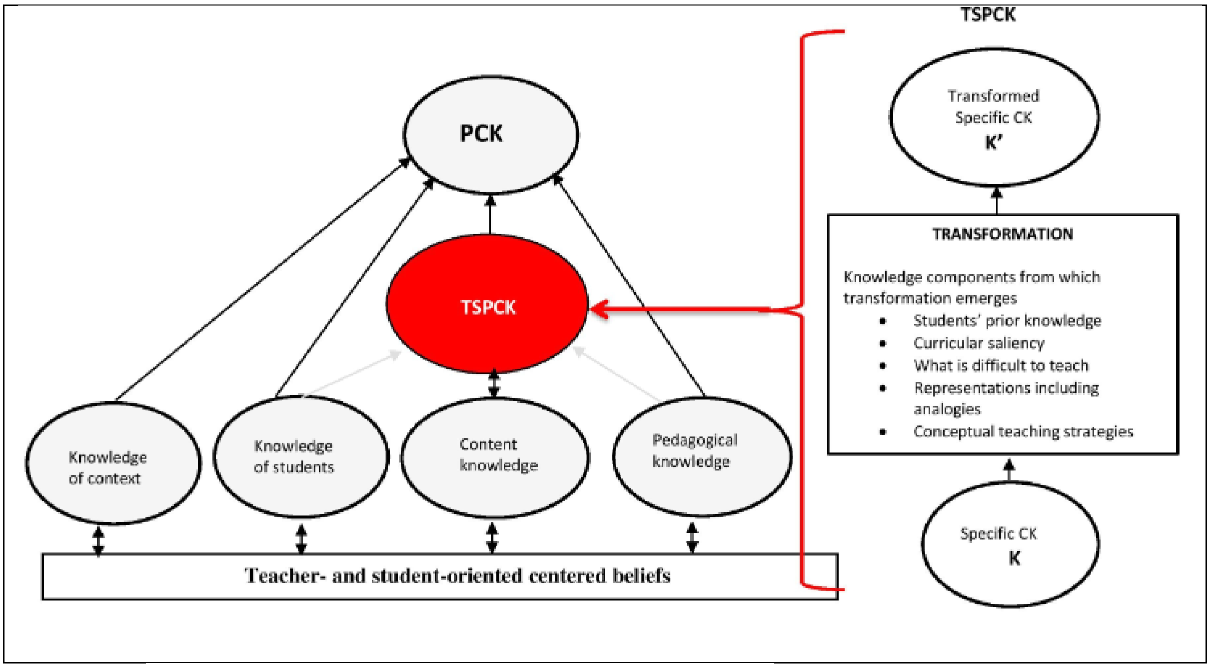


Figure 2. 3: **Topic Specific PCK model (Mavhunga 2012)**

This model places the emphasis on conversion of the content knowledge using five components. The specific content knowledge(K) is converted or transformed into content knowledge for teaching such that it can be understood by learners. To transform K to K'in order to be accessible to learners, five knowledge components are employed Even though student achievement is not guaranteed, but the use of TSPCK model in teaching brings good transformation of the CK. If these specific components are used to engage every content topic for example topics in science, the knowledge that will result will be easily accessible to learners, and the transformation of content transpires (Rollnick & Mavhunga, 2014).

2.6 Conclusion

The role of every teacher is to assist learners to comprehend content knowledge. So as a science teacher it is crucial to have sound content knowledge that can then be transformed for accessibility by the learners. Teachers use their PCK to teach every science content, and their

PCK develops over time. Teachers with developed PCK transform the topic better in a way that is easily accessible to learners. Also, PCK develops with learning experiences, which means when teachers are taking part in science education by studying postgraduate courses and attending the structured educational programmes, this kind of PCK is said to be personal-PCK. More importantly, teachers' PCK grows with experience when teachers are directly teaching learners in the classrooms and reflecting on their daily lessons.

3. CHAPTER THREE: METHODS AND MATERIALS

3.1 Introduction

In this chapter, the explanations for the methods and instruments of the study were presented. The discussion of the research design chosen and the importance behind the chosen methodologies in relation to the purpose of my study was also presented. Different instruments used for data collection and processes of data collection were described. The issues of trustworthiness and validity and the processes of ethical consideration followed were also discussed in this chapter.

3.2 Research design

The study employed Mixed Methods (MM) to examine the influence of experience on the quality of TSPCK for teaching a topic of chemical equilibrium. MM is chosen in this study because it is the method that sets free the researcher to utilize many methods for data collection and data analysis (Venkatesh, Brown & Bala, 2013). The main characteristic of mixed method research is that, it covers both qualitative and quantitative strategies concurrently or sequentially, to investigate a phenomenon of interest (Venkatesh, Brown & Bala, 2013). The qualitative method involves the collection of non-numerical data, this non-numerical data benefits the researchers to comprehend the interpretations of the phenomenon being researched (Njie & Asimiran, 2014). Qualitative method is "a form of systematic empirical inquiry into meaning" (Shank, 2002, p. 5). This numerical data could be used to find large-scale developments, and numerical data works with statistical processes to define important and correlation between variables that are investigated (Muijs, 2011). In this study, firstly, the qualitative design was employed to get non-numerical data, thereafter, non-numerical data collected was converted to the numerical data for the statistical interpretation of the results. 2002). Secondly, in terms of quantitative strategy Rasch software was used to provide a statistical interpretation of the data. The performances of the participants in the items were gathered from Rasch and compared (Rollnick & Davidowitz, 2015).

3.3 Research strategy

The study followed a group of qualified physical science teachers, these teachers had eight years of experience of teaching. The study employed a case study research strategy as it allows for an examination of teachers' content knowledge and topic-specific pedagogical content knowledge in order to gain deeper understanding of the influence the experience had on their understanding and teaching of topic chemical equilibrium. Case study was chosen as a research strategy, in this case was believed to be relevant as it enabled the researcher to collect the data using multiple sources (Rowley, 2002).

3.3.1 Case study

This study employed a case study as a research strategy. A case study is a case or a single subject in a field of research that can be investigated more than once. It is described as a fit instrument for the foundation, investigative stage of a study and as an exploratory for the development of the 'more structured' instruments that are necessary for investigations and researching (Rowley, 2002). According to Yin (2003), a case study strategy is used to discover circumstances in which an intervention is being assessed.

As Rowley (2002) argued that, case studies are more relevant in cases that includes descriptions, investigations or explanation of the trend within the research study, therefore the intention of this study was to attempt to explore and describe the influence of experience on the quality of teacher CK and TSPCK. Furthermore, case studies give researchers an opportunity to gain deeper insight on the research problem and may facilitate in understanding and describing a situation. Therefore, it provides the researcher to explore more through information search concerning the field of interest. According to Cohen, Manion and Morrison (2007), case study is seen as a research pattern deeply establishing description, interpretation, and analysis of certain phenomenon through searching of data from data sources. The broad intention of the case study is to define, document and explain a case. Many pre-service teachers are exposed to TSPCK construct, and many types of research have been done on developing the pre-service teachers. However, I never came across the study whereby a similar group of teachers been followed eight years of completing their degrees to check whether there is a change in the quality of CK and TSPCK. Therefore, the purpose of this study was to establish if there will be a change over time. This study comprised of data collection from a group of qualified physical science teachers. These teachers have eight years' experience of teaching in South African schools. The focus of the research questions in this study was to gain an understanding of the influence of experience on the teachers' quality of content knowledge and topic-specific PCK on a topic chemical equilibrium. Also, to gain insight into teachers' experience over a period of eight years. This case study strategy is important in this research because it will give the researcher a chance to explore wider and deeper about how much content knowledge teachers have after 8 years of completing their degree, and how the experience has influenced teachers' quality of TSPCK in topic chemical equilibrium.

3.4 Population and Sampling of the Participants

The important initial step in the collection of data is the selection of participants (Englander, 2012). Both population and sampling should be identified. Population refers to a set of subjects such as individuals, groups, institutions, countries, etc. The population comprised of sixteen (16) in-service physical science teachers. These teachers were exposed to physical science methodology course in their final year (fourth year) of study. Only qualified physical science teachers who completed their B.Ed. in 2011 at Witwatersrand University in Johannesburg South Africa constituted the population in this study. They were chosen because their CK and TSPCK in a topic chemical equilibrium was developed through intervention, also their quality of TSPCK was documented. It is therefore teachers who were available to take part in this study were sampled. A sample is a strict subset of the population. Samples can be chosen specifically or be random chosen. For this study, only the sample of seven (N=7) in-service teachers was part of the participants. These cohort of qualified physical science teachers were taking part in this study by virtue of being available and interested. Below is the table that shows the list of participants in this study. On the left side of the table are teacher codes, and on the right side is their qualifications.

Table 3. 1: **Participants taking part in this study**

Number	**Teacher code**	**QUALIFI-CATION(s)**	**Gender**	**Major subject**	**Teaching experience in years**	**Taught physical science and grade**
1	KMA 1	B.Ed.	F	Physical science	8	Yes (grade 10)
2	MLA2	B.Ed.	M	Physical science	8	Yes (grade 10 only)
3	MCA 3	B.Ed.+ BScHon	M	Physical science	8	Yes
4	NMA 4	B.Ed.+HON(SE)	F	Physical science	8	No
5	MPA5	B.Ed. (Hon*)	M	Physical science	8	Yes (grade 12)
6	MSA6	B.Ed.+ Hon	M	Physical science	8	No
7	GNA7	B.Ed. + Hon (Math)	M	Physical science	8	No

Hon*= he did only honours course work

All these teachers majored with physical science, and they are now qualified physical science teachers holding Bachelor of Education degrees. Four of these seven teachers had honours degree as their second qualification.

3.5 Research Instruments

Two instruments which are CK and TSPCK test and interviews were used to collect data in this study. Both instruments are tested and validated and taken from Mavhunga (2012), they are designed to measure both CK and TSPCK within the chemical equilibrium topic. CK instrument was used to assess teachers' content knowledge about chemical bonding, TSPCK instrument assesses teachers' PCK. Interviews used in this study are in two folds, semi-structured interviews, and stimulated recall interviews. All instruments are described in the next sections.

3.5.1 CK Chemical equilibrium instrument

CK instrument is specifically designed to assess content knowledge in chemical equilibrium. The instrument is divided into three categories, and each category contains questions. The total number of questions in this instrument is 13. Category A contains four questions, category B contains 6 questions and Category C contains three questions. Below is the extract from the CK chemical equilibrium instrument attached in appendix 1.

CHEMICAL EQUILIBRIUM ACHIEVEMENT TEST

CATERGORY A:

1. Consider the reaction which is at equilibrium

$$C_2H_5NH_2\,(aq) + H_2O\,(l) \rightleftharpoons C_2H_5NH_3^+\,(aq) + OH^-\,(aq)$$

Look carefully at the equation and decide which of the following statements about the reaction at equilibrium is **CORRECT.**

A. The reverse rate of reaction is lower than the forward rate of reaction.
B. The forward rate of reaction is greater than the reverse rate of reaction
C. The forward and reverse rates are equal.
D. The concentration of reactants is higher than that of products.
E. The concentration of reactants is lower than that of products.
F. The concentration of reactants and products is the same.

i. A and D only
ii. C and F only
iii. B and E only
iv. C and E only
v. A and E only

Your answer is.... Provide a detailed explanation for the answer you have chosen.

Figure 3. 1: **An extract CK- Chemical Equilibrium test**

- In category A, the first question assess the meaning of double arrows of the reaction at chemical equilibrium, the second question evaluates teachers' knowledge about equilibrium constant (Kc) expressions and the rate of change in concentration, while the third question assesses the stoichiometric ratios of molecules, and the fourth evaluate the interpretation of reactions at a microscopic level and changing conditions.

- In category B, the first two questions deal with the use of Le-Chatelier's principle, followed by the third question that assesses the writing of equilibrium constant expression, the fourth assesses the calculation of KC. The fifth and sixth questions consist assess the shift and factors affecting the equilibrium position.
- In Category C, the first question assesses the interpretation of microscopic diagrams when one factor is changed, whereas the last two questions examine the interpretation of the concentration-time graph at equilibrium.

Table 3.2 shows the items included in the CK test and the content assessed, items are mostly line up to grade 12 chemistry curriculum. Detailed items of the test are found in the appendix.

Table 3. 2: **Descriptions of items in the Content Knowledge Test**

Item number	Concept assessed	Grade	Comments
1	The meaning of double arrows, long and short arrows ($\rightleftharpoons$) of the reaction at equilibrium.	12	
2	The Kc expression, and the rate of change in concentration.	12	
3	The stoichiometry (ratio of molecules)	12	
4	The interpretation of reactions at microscopic and changing conditions.	Not in school curriculum	Item 3 assess the understanding of the reaction at microscopic level when one of the conditions is changed, and not part of the school curriculum.
5(a) and 5(b)	The use of Le-Chatelier's principle	12	
6	Writing of Kc expression.		
7	The calculation of Kc.	12	
8(a),8(b), 9(a), 9(b) and 9(c)	The equilibrium shift, and factors affecting equilibrium position.	12	
10 (a) and 10(b)	Concentration-time graph at equilibrium.	12	These items assess drawing of concentration-time graphs. But the concept of drawing these graphs is not explicitly assessed but interpretation of these graphs is assessed.

Only one item from above does not assess grade 12 content, however, it assesses teacher's understanding of the use of representations at a microscopic level, which is important when explaining the behaviour of chemical reactions at a microscopic level.

3.5.2 TSPCK Chemical equilibrium instrument

The TSPCK chemical equilibrium instrument is assessing ways teachers transform content knowledge. There are five categories (A-E) in the TSPCK chemical equilibrium instrument. The instrument is attached in appendix 2. The descriptions of questions as per category are as follows: Category A covers typical student responses. It necessitates participants to point out how they would respond to learners in each case, i.e. what comment would they give learners. Category B narrates to planning and sequencing of the topics. Category C enquires participants to reflect on which topics regarding chemical equilibrium are difficult to teach or learn.

Category D offers different types of representations and analogies. Participants were expected to think about which ones they find more valuable and then fill in the table relating to the effectiveness of these analogies in the classroom setting. Category E offers participants with learner's exercise and needs participants to think about how they would support a learner to develop a conceptual understanding of chemical equilibrium. Figure 3.2 below is the extract from the TSPCK instrument.

CATEGORY A: LEARNERS' PRIOR KNOWLEDGE

1. What comment would you write on a learner's script who writes:

A reaction reaches equilibrium when the concentrations of the products and reactants are equal.

Response A: No; when a reaction reaches equilibrium it does not mean the concentrations of the reactants and products are equal. The concentration of reactants and those of products are not equal at equilibrium. Sometimes the concentration of reactants is more than that of products and vice-versa. It depends on the type of reaction.

Response B: No; when a reaction reaches equilibrium the concentration of the products and the reactants are not equal. Equilibrium is reached when both reactions proceed at the same rate.

Response C: No; the concentration of reactants and products at equilibrium are not necessarily equal. Each reagent may have its own concentration which is different to the other. What ensures a reaction to be at equilibrium is the rate at which the forward and the reverse reaction occur. For equilibrium to occur this rate must be equal for both reactions.

Response D: None of the above

Choose your response, and use the space below to expand on your choice.

My choice is Response.....

Figure 3. 2: **An extract CK- Chemical Equilibrium test**

In summary, the five categories involve questions about how participants address the five TSPCK knowledge components, LPK; CS; WDT; REP; and CTS (Mavhunga & Rollnick, 2013).

3.5.3 Qualitative Interviews

Qualitative interviews are commonly done on face-to-face (Novick, 2008). This study used telephonic interviews to collect qualitative data from seven participants. The telephonic interview was chosen because the costs are minimal, and it is time-saving (Stephens, 2007). Also, the participants were coming from different provinces all over South Africa. So, travelling to all the places with little budget and at a shorter period, it was not possible. Two types of interviews were used, namely, stimulated recall interviews and semi-structured interviews. Both interviews were used to gain an understanding of the physical science teachers' perceived reasons for a change or lack of change in the quality of their topic specific PCK. Firstly, stimulated recall interviews were administered, followed by semi-structured questions (see appendix 6), the stimulated recall interviews emanated from the analysis data collected from both CK and TSPCK instruments. Both interviews were used to address the second sub-research questions. The stimulated recall interviews helped the researcher to illuminate teachers' perceived reasons for the change or lack of change in the quality of TSPCK. However, before the stimulated recall interviews could take place, the qualitative data collected through CK and TSPCK instruments were scored (quantified) and analysed, then participants who scored higher and lower were identified. Participants who were interviewed were selected based on the results they got in their responses in the CK and TSPCK instruments. Purposefully, the interview is chosen because it allows reinterpretation of data as an interactive process, help to verify facts, contributes to triangulation procedures (Scott & Morrison, 2006).

3.5.4 Documents

The CK and TSPCK tests on chemical equilibrium that were collected before the participants left the university in 2011 were used in this study. These documents are like the ones explained above and are attached in the appendix. The qualitative data was already collected in 2011 before the participants in the study conducted by Mavhunga (2012) in improving pre-service teachers' topic-specific PCK with both_CK and TSPCK chemical equilibrium instruments. These documents formed part of the data in this study, the data collected with these two documents were compared with the data collected in the current study.

3.6 Data collection and data handling

For this study, two CK and TSPCK instruments, and interviews were used to collect the data. At first, participants completed both CK and TSPCK instruments, whereby they were sent both instruments by means of email. The reason for sending them the tools through email is because they are teaching far from each other in different provinces all over South Africa, and it was not plausible for them to converge at a commonplace. They were expected to complete both tools within a period of two to three weeks since it requires ample time to plan to teach a whole topic (e.g. chemical equilibrium). The second part of the data collection process is through telephone interviews. According to Scott and Morrison (2006), telephone interviews are said to be the alternative way of interviewing process to face-to-face, and it is valid to face-to-face interviews. The 2011 data collected using CK and TSPCK chemical equilibrium instruments in 2011 from pre-service teachers were requested from Wits university scholar, then compared with the data collected from in-service teachers in this study with similar instruments. These data were collected from similar teachers who were pre-service teachers in 2011, but now they are in-service teachers with eight years of teaching experience.

The data collected through the CK instrument was marked with the memorandum of correct answers. Completed TSPCK instruments were scored using TSPCK rubric (Mavhunga, 2012). The rubric contains four levels of competency namely: "level 1 (Limited), level 2 (Basic), level 3 (Developing), and level 4 (Exemplary)". Figure 3.3 below is an extract of the TSPCK-rubric used to quantify the TSPCK tools.

	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.

Figure 3. 3: **An extract TSPCK- rubric showing interactions of components.**

The table below shows the scoring structures of the five items using the TSPCK rubric. The minimum score is 1 which shows limited knowledge, and the maximum score is 4 which shows exemplary. Whereas score 2 is basic and 3 is developing level of competency (See table 3.3 below).

Table 3. 3: **Scoring structure of TSPCK-tests**

Item	Max Score	Limited	Basic	Developing	Exemplary
LPK	4	1	2	3	4
CS	4	1	2	3	4
WDT	4	1	2	3	4
REP	4	1	2	3	4
TS	4	1	2	3	4

All raw scores were recorded on the spreadsheet. Thereafter the validation process of the scores took place, the process is explained in section 3.8. Upon completion of the validation processes, the data was further process using Rasch Unidimensional Measurement Model (RUMM) software for statistical analysis. Full details are provided in section 3.7.1 below. The raw scores generated using both CK memo and TSPCK rubric were analysed. Firstly, quantitative analysis from Rasch was done to compare the performance of the participants' 2011 CK tests and 2019 CK tests. Secondly, qualitative analysis was undertaken to compare their quality of participant's content knowledge in CK tests. Thirdly, the quantitative analysis focused on the comparison of the participants' performances in 2011 TSPCK-tests and 2019 TSPCK-tests. Then followed by the qualitative analysis of the teachers' response in the TSPCK instruments. Further analysis compared the relationships between the CK and TSPCK of the participants.

The data collected through telephonic interviews was transcribed. The interview transcripts were examined closely to identify meanings or themes that emerged from the data using a thematic analysis approach, this approach is explained at a later stage on section 3.7.3. Discussion of the TSPCK-test results and summary statistics are presented in the next chapter.

3.7 Analysis of the data

In this study mixed-method approach of analysis was employed in this study. Both statistical and thematic analysis approach were used. The discussion on how data analysis occurred is discussed in the next sub-sections.

3.7.1 Quantitative and qualitative Analysis

Mixed methods were chosen as the research design for the study. Both quantitative and qualitative analysis approach. Qualitative analysis involved Rasch analysis which provided statistical analysis of the data, whereas qualitative analysis involved both item analysis and thematic analysis as they were described at a later stage. Firstly, the qualitative data collected through the CK and TSPCK instruments was converted to quantitative data using both CK memorandum of correct answers and validated TSPCK rubric. The generated scores from the CK instrument were converted into percentages, then comparison of the participants' performances in the CK was done, detailed explanation is given in chapter 4. Quantitative data generated form the TSPCK-instrument was subjected to Rasch analysis.

The Rasch was done using Rasch Unidimensional Measurement Model (RUMM), which is a model that can take non-linear raw score test data and convert into linear measures (Boone and Rogan, 2005). A Rasch analysis reported the summary statistics of the data, person measures and item difficulties on the same linear scale, which allows the researcher to be able to do comparisons on a qualitative level of analysis. The raw scores were put to Rasch analysis to offer evidence of construct validity and instrument reliability, details are discussed in chapter 4.

Secondly, Quantitative data analysis was followed by a series of qualitative analysis techniques to gain understanding into the teachers' knowledge shifts in teaching chemical equilibrium after eight years of experience. Qualitative analysis was done to make comparisons between the participants' 2011 TSPCK responses and 2019 TSPCK responses. The focus of this analysis is to find the in-depth understanding of their quality topic-specific PCK. Participants' use of TSPCK knowledge components influenced their quality of TSCPK. There were five components in the TSPCK instruments, these categories consisted of items. Analysis was done by selecting items from all the five components, the process of selection was guided by teachers' performances, and all levels of their performances were catered for. The purpose of this item analysis was done in relation to answering the first research question, this question seeks an understanding of the quality of teachers' CK and TSPCK in teaching chemical equilibrium after eight years. It is therefore, to address this question, the researcher identified important patterns per component from quantitative data in the TSPCK instruments in relation to participants' performances.

Finally, qualitative data collected through interviews was analysed to identify teachers' perceived reasons for change or lack of change in their quality of TSPCK in a topic over the period of eight years. Thematic analysis (TA) method was used to analyse teachers' responses in the interview transcripts. This method was chosen because of its accessibility and flexibility, which allows the researcher to focus on the data in many ways (Braun & Clarke, 2012). TA refers to step by step approach of identifying, organizing, and offering understanding into patterns of themes across a data set (Braun & Clarke, 2012). In the process of analysis, the focus was on identifying important themes or topics that emerged from the transcripts in relation to research question number two. Initially, all the transcripts were read to get familiar with teachers' responses. Thereafter, codes that are relevant to the research questions were generated, including the repeated codes emanated from the data, and recorded on a table. Table 3.4 below showed the example of codes that were generated.

Table 3. 4: **Extract from Fran's interview to illustrate codes**

Transcripts	**Codes**
Frans: I teach grade 12 physical sciences, and it marked 8 years now. But I have realised still I lack strategies to apply when teaching science. I still have lot of misconceptions about the topic, I do not develop myself and that causes problem in class. Again, we are not developed thus contribute to poor results. I attended few workshops, but we discussed Newton's laws and some parts of organic chemistry. Our curriculum advisor does too much physics content than chemistry, I do not remember doing chemical equilibrium at workshops. Often, curriculum advisors talk less about content, they only talk about exam guidelines and CAPS policy. But I think I need to develop myself.	teach grade 12 physical sciences lack strategies do not develop myself workshops curriculum advisors talk less about content to develop myself.

Codes were identified for each individual teacher, then analysed. Codes and sub-codes emanated from the data set were created. This process involves reviewing the coded data who seemed to have similar features, were grouped together to form sub-codes to make meaningful patterns of data. Findings from data transcripts were reported in chapter 4.

3.8 Validity and trustworthy

Validity denotes the accuracy or truthfulness of a justification, interpretation, and description of one's field of discipline (Maxwell,1998). Whereas trustworthiness denotes to the quality of both results and data and is thought to have four component part being; credibility, transferability, dependability, and conformability (Letts, Wilkins, Law, Stewart, Westmorland, 2007). Validation of mixed methods study comprises of measuring the quality of results. Also, includes the interpretation of results from all the data (both qualitative and quantitative) in the research investigation (Venkatesh, Brown, Ball, 2013). A statistical method called Rasch was used in this study to determine validity and reliability indices from the data collected through CK and TSPCK instruments. The validation of the scores was done, peer validation approach was employed, whereby the researcher gathered with other two academics to score selected instruments completed by teachers. Thereafter, the differences in scores were discussed, and the consensus was reached on the final score.

3.9 Ethical consideration

In this study, the processes of data collection started by considering research ethics. Firstly, the application for ethical clearance was submitted to the University of Witwatersrand ethics committee. To collect data the formal permission was granted by the ethics committee at Wits. All participants who volunteered to take place in this study were knowledgeable about the processes, expectations, and intentions of the study in the consent form, and they signed the consent form and, indicated that they volunteer to take place in the study. The privacy of all participants was sustained throughout the study, their names were not exposed to anyone, only the researcher knew the names of participants. For confidentiality purposes, research will not disclose any information that is considered confidential to others. Throughout the collection of the data process, no one was identified by their real names, and the participants' names will not be disclosed in the reports. So, pseudonyms were used to identify participants. Data collected is kept safe and inaccessible to anyone besides the researcher. After three years of completing the study, all instruments used to collect the data will be demolished.

3.10 Conclusion

This chapter focused on the research methods and materials used for data collection, also on how analysis of data was conducted. Research validity and trustworthiness and ethics of this study were outlined in detail. Next chapter presents results, analysis, and interpretation of data of this research.

4. CHAPTER FOUR: DATA ANALYSIS

Results, Analysis, and Interpretation. In this chapter, the results of the participants of the tests in 2011 and the ones in 2019 are compared. Both quantitative and qualitative analysis were done. Quantitative analysis was done first, thereafter a qualitative analysis of the participants' responses from TSPCK followed. Finally, the analysis of the qualitative interviews data collected from all the seven teachers was presented.

4.1 Introduction

The overarching intention of this study is to understand the influence of experience on the quality teachers' CK and TSPCK. A TSPCK construct was chosen in this study to explain the teachers' knowledge about teaching the topic of chemical equilibrium. Two validated instruments were used to collect the data that expose the teachers' content knowledge and topic-specific PCK. This chapter provides analysis of the teachers' responses from both CK and TSPCK instruments, to seek understanding of how the experience might influence their knowledge for teaching chemical equilibrium. Quantitative analysis was done for both CK and TSPCK tests to provide comparisons for teachers' performances, also Rasch analysis was done to provide statistical analysis of the data. Thereafter, a qualitative analysis of the teachers' responses was done to get the insight of teacher reasoning using components of TSPCK. The relationship between CK and TSPCK was further investigated, to find any trends between the teachers' content knowledge and topic-specific PCK. Analysis of the interviews is presented in the next chapter (chapter 5).

4.2 Quantitative analysis of the CK test

The focus of the first research question was to seek an understanding of the influence of experience on the quality of teachers' TSPCK and CK in teaching chemical equilibrium after 8 years of completing B.Ed. Therefore, to find an answer to the first question, a quantitative analysis was done to compare the performances of the participants. So, this section presents the results of teachers' performances in both 2011 and 2019 CK tests. Below is the table that shows the raw scores of seven (7) teachers (table 4.1). The raw scores were obtained from the CK test using the marking memo as discussed in the previous chapter. The total marks of the CK test was 32, all the individual marks obtained by the teachers in the CK tests were converted to percentages to compare their performances. At the bottom of the table mean scores were calculated.

***Table 4. 1:* Results of the 2011 and 2019 CK-tests**

Teacher code	2011 score	% 2011 score	2019 score	% 2019 score
KMA1	12	37,5	21	65,6
MLA2	26	81,3	21	65,6
MCA3	23	71,9	24	75,0
NMA4	17	53,1	19	59,4
MPA5	23	71,9	25	78,1
MSA6	18	56,3	17	53,1
GNA7	24	75	17	53,1
Mean	**20,4**	**63,9**	**20,6**	**64,4**

The overall average performance in the CK test score in 2011was 63.9%, whereas in 2019 CK test score is 64,4%. That means the CK test average score in 2019 was 0.5 higher than that of 2011 CK test. Both in 2011 and 2019 CK tests, three participants performed less than the average score. Which is believed to be the reason why the average shift is very small. Despite the small average shift of 0.5, six participants performed more than 50% in 2011 CK tests, whereas seven participants performed more than 50% 2019 CK tests.

Individual performances are compared in the Table 4.2 below. The performances of the participants in the CK-test were further converted to normalised gain, to get a clear indication on their performances as shown below (Table 4.2). Normalised gain is the actual gain, divided by maximum score and minus the initial score. The actual gain is the difference between the final score (Sf) and the initial score (Si).

Table 4. 2: Performance in the 2011 and 2019 CK-tests

Number	Teacher code	2011 Score (%)	2019 Score (%)	Actual gain	Normalised gain
		Si	Sf	Sf-Si	(Sf-Si)/ (100- Si)
1	KMA1	37,5	65,6	28,1	0,45
2	MLA2	81,3	65,6	-15,5	-0,83
3	MCA3	71,9	75,0	2,5	0,09
4	NMA4	53,1	59,4	6,9	0,15
5	MPA5	71,9	78,1	5,3	0,19
6	MSA6	56,3	53,1	-4,8	-0,12
7	GNA7	75,0	53,1	-23,6	-0,94
Average		**63,9**	**64,4**	**0.5**	**0,02**

Four out of seven teachers (numbered 1, 3, 4, and 5) showed the improvement in the content knowledge after 8 years of experience. To compare two teachers, numbers 1 and 5, teacher 1 obtained a final score of 65.6% and for teacher number 5 is 78,1%, which is the highest score obtained in 2019 CK-tests. But teacher number 1 with KMA1 code is the most improved with the actual improvement of 28,1%. Noticeably, teacher KMA1 is the most improved from a lower initial score of 37.5% in 2011, whereas teacher MPA5 improved from a higher initial score in the 2011 CK test. Thus, the normalised gain of teacher number 1 is higher. The negative value of normalised gain indicates that teachers' content knowledge deteriorated after 8 years. Only three teachers numbered 2, 6, and 7 showed a decline in their CK-test scores after eight years. Despite the decline, the results above showed that some teachers had reasonable CK for teaching chemical equilibrium, and there is an average increase even though it is significantly small.

Performances of all seven teachers do not show a specific trend. The profiling of these teachers is shown in the Table 4.3 below. In 2011 CK tests all participants were still undergraduate students doing their fourth year of study and majored in physical science. During 8 years of teaching experience among them, four obtained honours, their codes are MCA3, NMA4, MSA6 and GNA7. Two of these teachers with teacher codes MCA3 and NMA4 hold honours degrees in science education. Teacher MAS6 have honours in leadership and management, and teacher GNA7 have honours degree in mathematics. On the other hand, teacher MPA5 honours qualification is half completed, since only the course work requirement is fulfilled. Five teachers out of seven had never taught physical science in grade 12 throughout eight years of their experience in teaching. It is only two teachers (MCA3 and MPA5) who taught grade 12 throughout their teaching experience.

Table 4. 3: **Participants' performance and their profiles**

2011 CK test				**2019 CK test**				
Number	**Teacher code**	**QUALIFI-CATION**	**2011 Score (%)**	**Teacher code**	**QUALIFI-CATION**	**Teaching experience**	**Taught physical science and grade**	**2019 Score (%)**
1	KMA1	U	**37,5**	KMA1	BE. d	8	No	**65,6**
2	MLA2	U	**81,25**	MLA2	BE. d	8	Yes (10)	**65,6**
3	MCA3	U	**71,88**	MCA3	BE. d+ BScHon	8	Yes (12)	**75,0**
4	NMA4	U	**53,13**	NMA4	BE. d+ HON(SE)	8	No	**59,4**
5	MPA5	U	**71,88**	MPA5	Bed(hon*)	8	Yes (12)	**78,1**
6	MSA6	U	**56,25**	MSA6	BE. d+Hon	8	No	**53,1**
7	GNA7	U	**75**	GNA7	BE. d+ HON(Math)	8	No	**53,1**
	Average		**63,9**					**64,4**

This is an indication that physical science qualified teachers not teaching the subject in grade 12, can show a negative impact on their content knowledge. However, there are two teachers with improved content knowledge even though they had never taught grade 12. Teachers indicated with code KMA1 and NAM4 (highlighted in green) reflected to have better content knowledge in 2019 CK tests than in 2011 CK test, even though the shift is not significant. Two teachers who taught physical science in grade 12 for the period of eight years showed significant improvement in their content knowledge. Teachers' improvement or lack of improvement in content knowledge was further investigated through qualitative analysis of their responses from topic-specific PCK, and these are coming in the next discussion. Item analysis of the CK responses was not done separately, because the content knowledge appeared in both CK and TSPCK is similar, however, TSPCK-tests assessed more on the teaching part of chemical equilibrium. The quality of both CK and TSPCK can also be observed in the analysis of the teachers' responses in the TSPCK tests.

4.3 The Topic-specific-PCK tests

4.3.1 Results of the 2011 and 2019 TSPCK tests

The participants' performances in the 2011 and 2019 TSPCK tests are given below ranging from level 1 to 4 as discussed in the previous paragraph. There were seven participants in total each of the participants was allocated teacher code (i.e. KMA1). Table 4.5 presented teachers' scores for the 2011 TSPCK tests and 2019 TSPCK tests per component. Averages are calculated at the bottom of the table to show the overall shifts per component, overall performances per-individual is discussed at a later stage.

Table 4. 4: **Raw scores of 2011 and 2019 TSPCK-tests**

• **2011 TSPCK Scores**									• **2019 TSPCK Scores**						
Number	**Teacher code**	**QUALIFI-CATION**	**LPK**	**CS**	**WDT**	**REP**	**TS**		**Teacher code**	**QUALIFI-CATION**	**LPK**	**CS**	**WDT**	**REP**	**TS**
1	KMA1	UG	3	3	3	3	1		KMA1	B.Ed.	3	2	3	3	3
2	MLA2	UG	3	2	2	1	1		MLA2	B.Ed.	3	2	3	3	2
3	MCA3	UG	3	3	3	4	3		MCA3	B.Ed. +HON	4	4	3	3	3
4	NMA4	UG	3	3	3	3	3		NMA4	B.Ed. +HON	2	3	2	3	2
5	MPA5	UG	3	3	3	3	3		MPA5	B.Ed.+ **hon***	3	4	2	4	3
6	MSA6	UG	4	4	3	4	3		MSA6	B.Ed. +HON	3	2	3	3	3
7	GNA7	UG	3	3	2	1	1		GNA7	B.Ed. +HON	3	2	3	2	2
	Average		**3,1**	**3,0**	**2,7**	**2,7**	**1,9**		**Average**		**3.0**	**2,7**	**2,7**	**3,0**	**2,6**

Averages per component indicated that there is declined from 3.1 to 3.0 and 3.0 to 2.7 under LPK and CS, respectively. There is no average shift in WDT. The two most improved categories are REP and TS with the shift from 2.7 to 3.0 and 1.9 to 2.6, respectively. Although averages do not reflect the performance per individual, however, the researcher can get an overall picture of the participants' performance per component. The comparisons of participants' performances per component are discussed later in this chapter.

More information about performance per person per component was obtained through Rasch analysis. Raw scores were subjected to RUMM software as explained in the previous chapter, and Rasch analysis was done. Firstly, the 2011 and 2019 data were put together to meet the minimum requirements for RUMM programme. The minimum of 10 people is needed for RUMM programme to be able to run for analysis, therefore the data was stacked. The table below (table 4.6) shows the combined (stacked) data of the TSPCK tests before it was put to Rasch. The data below shows a total of 14 participants, the 2011 data and 2019 data were combined.

Table 4. 5: **Staked data for TSPCK-tests**

Teacher code	**QUALIFI-CATION**	**LPK**	**CS**	**WDT**	**REP**	**TS**
KMA1	U	3	3	3	3	1
MLA2	U	3	2	2	1	1
MCA3	U	3	3	3	4	3
NMA4	U	3	3	3	3	3
MPA5	U	3	3	3	3	3
MSA6	U	4	4	3	4	3
GNA7	U	3	3	2	1	1
KMA1	Bed	3	2	3	3	3
MLA2	Bed	3	2	3	3	2
MCA3	HON	3	4	3	3	3
NMA4	HON	2	3	2	3	2
MPA5	**Hon***	3	4	2	4	3
MSA6	HON	3	2	3	3	3
GNA7	HON	3	2	3	2	2

N.B Hon*=Teacher almost completed honours he did only course work

However, before comparative analysis of the test could be considered, it was important to engage other important aspects obtained from Rasch analysis. Firstly, the validity and reliability of the data were discussed, it was obtained from the summary statistics found from Rasch analysis.

4.3.2 Validity and reliability of the TSPCK

In the previous chapter, it was indicated that TSPCK tools were validated and tested, and they were used before. So, the aim is not to test the validity and reliability of the data obtained in the current study. Validity refers to the precision or reliability of description, conclusion, explanation, interpretation, or other sorts of account of the data (Maxwell, 1996). The aim here is to check the meaningful interpretation and the quality of findings of the data. RUMM offers evidence of validity and reliability indices from the data collected. It provides statistics about the items and persons to which the degree the items and persons fit the model. Expectations of the model are indicated by both item and person fit residuals. To reflect an excellent fit, the model is set to provide a mean fit residual of zero and a standard deviation of one (Boone & Rogan, 2005). Figure 4.1 below showed the summary statistics of the data collected through TSPCK instruments.

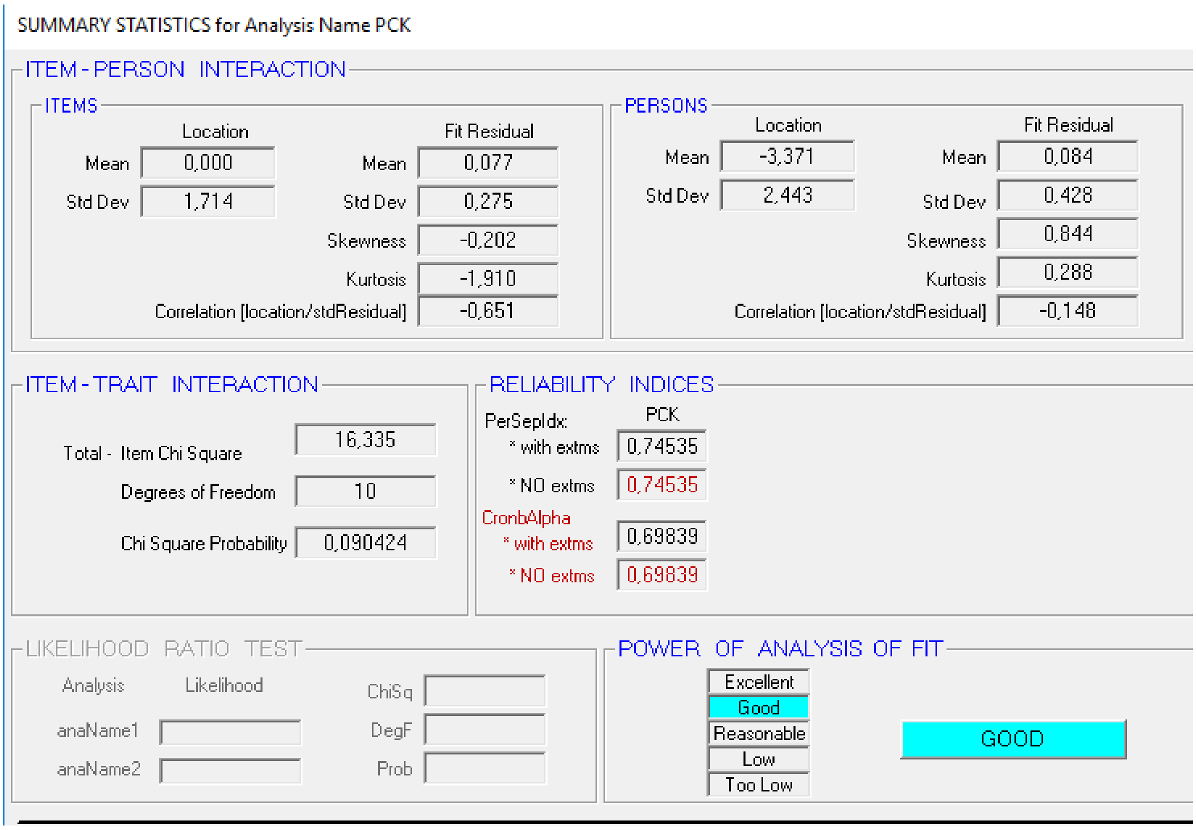


Figure 4. 1: **Stacked summary statistics for TSPCK test**

The power of analysis of fit from the summary statistics was good, which means the overall fit for both items and persons was good. To get a perfect fit, the residual range should be within

±2.5, and the item mean should be close to zero (Boone & Rogan, 2005). Mean item fit residuals was 0.07 (SD = 0.28) and person fit residuals 0.08 (SD = 0.43). Chi-Square probability is also within a ±2.5 fit residual range. Also, it was found that a Cronbach's Alpha was 0.7 with no extremes, which is an indication that reliability was acceptable.

4.3.3 Rasch analysis of the 2011 and 2019 TSPCK tests

Rasch analysis was done using RUMM 2030, and the item-person summary statistics was presented above. Also, the mean location score for persons was compared with the mean location of 0(zero) for items, in this case, items refer to five components of TSPCK. The performance of teachers in the TSPCK-tests is expressed as a location (Table 4.7). A mean person location greater than "0" (zero) shows that the test was easier, while a mean person location less than"0" (zero) shows that the test was very difficult. In table 4.7 below the performances in the TSPCK-tests obtained from Rasch analysis were arranged in ascending order of locations. Teacher number 9(MLA2) and teacher number 14 (GNA7) were found to be at the top of the table with location values -0,659 and -0.052 respectively. Those were participants who found the test most difficult in the 2011 TSPCK-test, however, the improvement was observed in the 2019 TPCK-test, and their location number increased significantly. Note that, similar participants were highlighted with similar colour for 2011 and 2019 tests, with different teacher numbers, see number 2 and 9 highlighted in yellow had similar teacher code. This is to make it easier to see or identify the shifts of the individual performances.

Table 4. 6: **Individual performance for TSPCK tests**

Teacher number	Location number	CS (-2,68)	REP (-091)	LPK (0,44)	WDT (1.51)	TS (1.64)	Teacher code	2011 or 2019 test
9	-0,659	2	1	3	2	1	MLA2	2011 test
14	-0,052	3	1	3	2	1	GNA7	2011 test
7	0,841	2	2	3	3	2	GNA7	**2019 test**
4	0,841	3	3	2	2	2	NMA4	**2019 test**
11	1,316	3	3	3	3	3	NMA4	2011 test
8	1,316	3	3	3	3	1	KMA1	2011 test
2	1,316	2	3	3	3	2	MLA2	**2019 test**
6	1,88	2	3	3	3	3	MSA6	**2019 test**
1	1,88	2	3	3	3	3	KMA1	**2019 test**
12	2,668	3	3	3	3	3	MPA5	2011 test
10	3,775	3	4	3	3	3	MCA3	2011 test
5	3,775	4	4	3	2	3	MPA5	**2019 test**
3	3,775	4	3	3	3	3	MCA3	**2019 test**
13	8,454	4	4	4	3	3	MSA6	2011 test

It was said above that the performances of participants were arranged in terms of location numbers from lower to higher value (see the second column). The participant with higher location number performed most, and they appeared to be at the bottom of the table. The most performed participant is number 13 with teacher code MSA6 in the pre-test, and he appears at the bottom of the table with the highest location value of 8.454 which is much greater than zero. In the 2019 TSPCK test, similar participant (number 6 with a teacher code MSA6) performed less, this means participant's quality of TSPCK of teaching the topic did not improve over the period of 8 years' experience. Also, a participant with a teacher code NMA4 also appeared to show decline in terms of the level of performance (see both numbers 4 and 11). Their lack of improvement will be further investigated through qualitative analysis

At the top of table 4.7 the components are arranged according to the levels of difficulties in ascending order from left to right (CS>REP>LPK>WDT>TS). An item with lower location number was found to be less difficult, the one with a higher location number appeared to be more difficult.

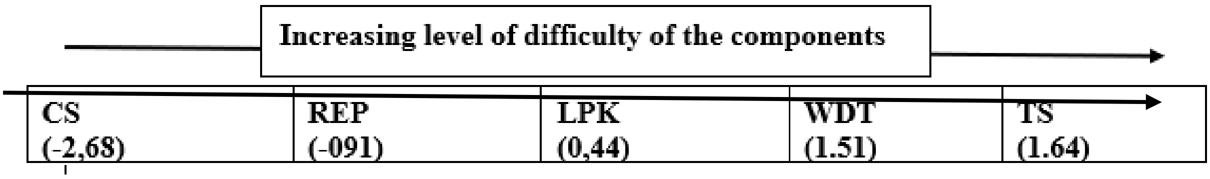


Figure 4. 2: **Overall level of difficulty of the components from Rasch analysis**

Curricular saliency (CS) appeared to be the easiest item with very low location number and Teaching strategies (TS). However, it was found to be the most difficult with a very high location number.

These components were further investigated through a qualitative look, to compare the shifts between the 2011 and 2019 TSPCK test scores, also to get a deeper meaning of the teachers' reasoning about teaching the topic.

4.3.4 Qualitative look at the TSPCK tests

The above discussion focused on the quantitative analysis of both CK and TSPCK tests. It was important to start with quantitative analysis to provide evidence or support for the knowledge shifts (if any) of both CK and TSPCK. Also, quantitative analysis helps the researcher to identify areas of discussion during qualitative analysis. Both raw scores and Rasch analysis showed that some participants had a better knowledge of these components of TSPCK about chemical equilibrium. However, some did not show any shifts in terms of understanding of these components. Table 4.8 below shows the comparisons of these knowledge components of the seven teachers, whereby the second column indicated teacher qualification. The remaining columns show both 2011 and 2019 raw scores per component as generated using the rubric.

Table 4. 7: **2011 and 2019 Raw scores for TSPCK-test per component**

Teacher number	**QUALIFI-CATION**	**LPK**		**CS**		**WDT**		**REP**		**TS**	
		2011	**2019**	**2011**	**2019**	**2011**	**2019**	**2011**	**2019**	**2011**	**2019**
KMA1	B.Ed.	3	3	3	2	3	3	3	3	1	3
MLA2	B.Ed.	3	3	2	2	2	3	1	3	1	2
MCA3	HON	3	4	3	4	3	3	4	3	3	3
NMA4	HON	3	2	3	3	3	2	3	3	3	2
MPA5	**Hon***	3	3	3	4	3	2	3	4	3	3
MSA6	HON	4	3	4	2	3	3	4	3	3	3
GNA7	HON	3	3	3	2	2	3	1	2	1	2
Average		3,1	3	3,0	2,7	2,7	2,7	2,7	3,0	2,1	2,6
2011 average score=2.7		**v/s**			**2019 average scores= 2.8**						

Hon*=Teacher almost completed honours he did on course work

The above raw data was then put into the histogram below to show the comparison on how participants performed in the 2011 TSPCK tests and 2019 TSPCK test.

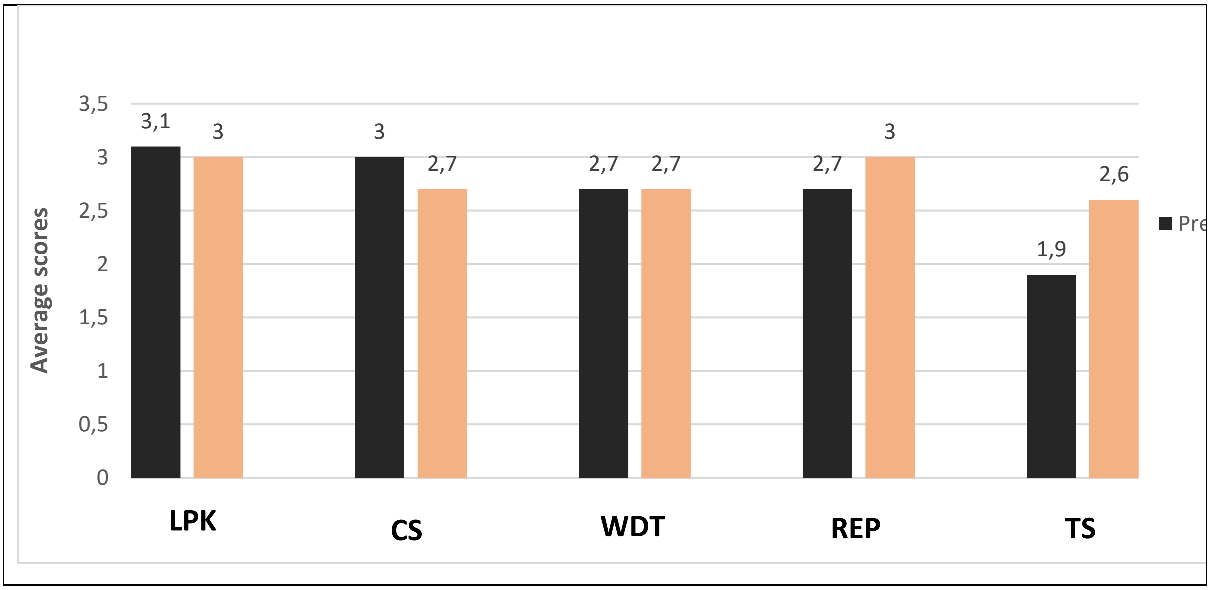


Figure 4. 3 **Comparison of the 2011 and 2019 TSPCK scores**

Generally, for all the seven participants, their average score of all five interacting components showed a shift from 2.7 to 2.8, this is an indication that their TSPCK has increased even though the shift is very low which is an average increase of 0.1 (see table 4.8). Despite the overall increase, there was no shift on component WDT, whereas two components showed declined (LPK and CS) and there was an average increase only on two components (REP and TS). The shifts or lack of shifts per knowledge component as indicated in the table will be further investigated through qualitative analysis of the responses to the prompts in the TSPCKS tests. The participants were selected based on their scores they got from the table above for further discussion, all categories of TSPCK were discussed below.

4.3.4.1 Engaging with a component: Learner's Prior Knowledge

Comparing the raw scores for 2011 and 2019 of the participants on component LPK, the averages showed a decline of 0.1 (see table 4.8 in the previous discussion). The 2011 selected participants (total=7) in this study, six out of seven obtained level 3 which means developing and only one participant got level 4 which means exemplary as indicated in the rubric discussed in the previous chapter. In 2019, out of the total of seven only one participant obtained level 4 (exemplary), five out of seven got level 3 (developing), only one got level 2 (basic). Generally, the results from Rasch analysis in the previous paragraphs showed that item LPK was found easy by most participants. Under this component LPK there were only two questions, and they were fully discussed in the previous chapter section 3.5.2. Figure 4.4 below shows the first question and, both 2011 and 2019 responses to the question from the TSPCK test under the component LPK. In the first question, participants were required to choose the response from the ones that are given, then further give reasons for their choices. Basically, this question was about the confrontation of student's misconception by identifying the problem and expand how a learner can be assisted to have a clear understanding.

CATEGORY A: LEARNERS' PRIOR KNOWLEDGE

1. What comment would you write on a learner's script who writes:

A reaction reaches equilibrium when the concentrations of the products and reactants are equal.

Response A: No; when a reaction reaches equilibrium it does not mean the concentrations of the reactants and products are equal. The concentration of reactants and those of products are not equal at equilibrium. Sometimes the concentration of reactants is more than that of products and vice-versa. It depends on the type of reaction.

Response B: No; when a reaction reaches equilibrium the concentration of the products and the reactants are not equal. Equilibrium is reached when both reactions proceed at the same rate.

Response C: No; the concentration of reactants and products at equilibrium are not necessarily equal. Each reagent may have its own concentration which is different to the other. What ensures a reaction to be at equilibrium is the rate at which the forward and the reverse reaction occur. For equilibrium to occur this rate must be equal for both reactions.

Response D: None of the above

Choose your response, and use the space below to expand on your choice.

My choice is Response.....

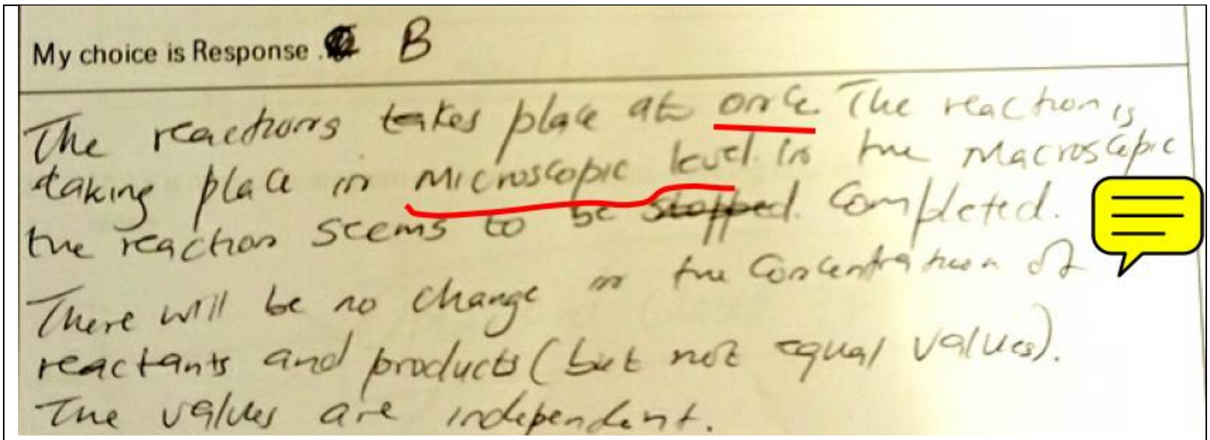
*Figure 4. 4***: An extract of the first item test from TSPCK tool on LPK**

All the responses from (A-C) that are given are scientifically correct, but they differ with the level of reasoning about the misconceptions (Mavhunga & Rollnick, 2013). Other responses are limited with the level of reasoning, response C is more detailed and accurate. An extract in figure 4.4 below presents two responses of teacher MCA3 in 2011 and 2019 to the LPK item from the TSPCK tool. Teacher MCA3 written responses showed the shift from developing to exemplary. In the 2011 response as shown in fig 4.4 below teacher MCA3 was expanding on his choice response C, he made the below statement "… *no change in concentration… does not mean they are equal".* These aspects that teacher MCA3 brought forward are essential for learners to learn about the reaction at equilibrium. The teacher's choice of response focused more on clarification of the misunderstanding the learner might have had. His explanations on the response is appropriate, as it shows the teacher's ability to identify learner's misunderstanding and it expands/rephrases on explanation the learner gave. However, the MCA3 explanation is limited to the use of the integration of other components of TSPCK in his explanation.

Response in 2011	Response in 2019
My choice Response: C *When equilibrium is rechead there is no change in concentration of either reactions or products however this does not mean they are equal*	*Responses A, B and C are not necessarily wrong.* *-Response A says it depends on the type of reaction. I would remove that if all reactions are performed in a closed system. If its Fe and S reacting to form FeS than that reaction does not reach chemical equilibrium.* *- Response B is correct but just needs to emphasise that at equilibrium the concentrations are constant.* *- Response C is also correct.*

Figure 4. 5: **An extract of the teacher MCA3 for 2011 and 2019 responses on first item test on LPK**

Teacher MCA3 in his 2019 response engaged on the three responses (A, B and C). He managed to see that all responses carry the potential to address learner misconceptions. The teacher further expanded on the responses, like A and B, because they were detailed and accurate to address the misconceptions compared to response C which is more correct. Most of the teachers (6 out of 7, which is 86%) chose response C which shows teachers' ability to identify misconceptions. Only one teacher chose response B, generally, all the teachers showed potential to address learner's misconception in their explanation. Considering the extract below from TSPCK-test written by teacher GNA7 in 2019 (see figure 4.6).


My choice is Response B

The reactions takes place at once. The reaction is taking place in microscopic level. In the macroscopic the reaction seems to be ~~stopped~~ completed. There will be no change in the concentration of reactants and products (but not equal values). The values are independent.

Figure 4. 6: **An extract of the teacher GNA7 responses on first item test on LPK in 2019.**

The teacher indicated that the reaction cannot be seen, however it takes place at microscopic level. There will be no change in concentration, and he also acknowledge the fact that at equilibrium the concentration of reactants of products are not equal. Teacher's effort of identification of misconception is seen more in his explanation above (see fig. 4.6). Other teachers made efforts in the second question from LPK, see the exact in figure 4.7.

2. In a classroom setting, which of the following responses will you choose to answer a learner who seems to be in doubt and asks you:

"Do both the forward and the backward reaction actually take place if a closed system is at equilibrium?"

Response A: Yes; the rate at which the forward reaction occurs is the same as the rate at which the backward reaction occurs.

Response B: Yes; for a reaction to be considered as at equilibrium, the rate of the forward reaction is the same as the rate of the reverse reaction. As products are formed, they decompose or react with each other and form reactants. In this way the reaction is kept at equilibrium.

Response C: Yes; a reaction that is at equilibrium has a forward and a reverse reaction. The forward reaction produces products and the reverse reaction produces reactants. Sometimes the concentration of products is higher than reactants, sometimes vice versa.

Response D: None of the above.

Choose your response, and use the space below to expand on your choice.

My choice is Response .....

Figure 4. 7: **An extract of the second item test from TSPCK on LPK**

As shown in figure 4.8 below teacher MCA3 showed an understanding of the **LPK**. In 2011 response, the teacher's explanation showed standardized knowledge, however, his explanation showed the appreciation of one other component which is representations by the use of the formula for rate of reaction (see response 2011) which indicates symbolic representation of the concept. The same teacher showed an improved response in 2019, the emphasis of important concepts is evidence of curricular saliency, words such as: *DYNAMIC, no change in concentration, if equilibrium lies to the right then more products have formed (*Le Chatelier's principle).

Response in 2011	Response in 2019
My choice response is A. *Rate=$\frac{\Delta c}{\Delta t}$ when equilibrium is reached there is no change in the concentration of the products & reactants. And the rate at which the forward reaction proceeds equals the rate at which the reverse proceeds.*	*I would use reaction A and B* *- I would emphasise the word DYNAMIC, there is no change in concentration per unit volume at equilibrium of either reactants or products (yield is not affected when a system is at equilibrium. It is a specific amount). However if equilibrium lies to the right then more products have formed even at equilibrium). The number of reverse effective collision (correct orientation and sufficient energy) is equal per unit time.*

***Figure 4. 8**:* **An extract2 of the teacher MCA3 responses (both 2011 and 2019) on second item test on LPK**

4.3.4.2 Engaging on a component: Curricular saliency

This component CS involves big ideas in a topic, sequencing of the concepts for learners' support, and the consciousness of the contextual knowledge required before teaching the topic (Mavhunga, 2012). An extract of this component is provided in figure 4.9 below. Under this component teachers were supposed to choose from the provided list the three big ideas to be taught about chemical equilibrium. The second part of the question required teachers to make a mind map or diagram of these three big ideas showing how they relate to subordinate ideas. The third part of the question required teachers to indicate topics that should be covered in chemistry prior to teaching chemical equilibrium. Also, they were supposed to put them in a sequence and provide reasons for the chosen sequence. The last part of the question requires the teachers to give reasons why it is important for learners to learn about equilibrium, by looking at three things, namely conceptual progression, application, and motivation or interest.

CATEGORY B: CURRICULUM AWARENESS

3. Questions 3.1 -3.4 relate to planning and sequencing of concepts.

3.1 What do you consider to be the **three main ideas** (main concepts) to be taught about equilibrium at Grade 12? Choose from the list provided.

Dynamic equilibrium	Equilibrium constant
Chemical reactions	Rate of reaction
Lê Chatelier's principle	Equilibrium shift
Factors that affect equilibrium	Calculation of equilibrium concentrations
Open and closed systems	Homogeneous and Heterogeneous equilibrium
Physical equilibrium	Forward reaction and reverse reaction
Extent of reaction	Other

1.
2.
3.

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

3.3 What topics must have been covered in chemistry before you can teach chemical equilibrium?

List of Topics to be taught before Chemical Equilibrium	Place them in a sequence (the one to be taught first , place it as No. 1)	Provide reasons for the proposed sequence
	1.	
	2.	
	3.	
	4.	

3.4 Why is it important for learners to learn about equilibrium? Identify reasons related to:

i. **Conceptual Progression**

ii. **Application**

iii. **Motivation or Interest**

Figure 4. 9: **An extract of teacher item test from TSPCK tool on CS.**

Figure 4.10 below shows the two responses from teacher MPA5 on the first item question on component CS. The item question was accessing the awareness on selection of main big ideas to be taught about equilibrium. Teacher MPA5 suggested that open and close systems factors affecting equilibrium and equilibrium constant are big ideas in teaching equilibrium. The teacher confused big ideas with subordinate concepts. The correct chosen big idea in 2011 response was equilibrium constant, whereas in 2019 response are dynamic equilibrium and equilibrium constant.

Response in 2011	Response in 2019
1. Open & Closed Systems 2. Factors affecting Equilibrium 3. Equilibrium Constant	1. Dynamic equilibrium 2. Le chatelier's principle 3. Equilibrium Constant

Figure 4. 10: **An extract of teacher MPA5 2011 and 2019 response on selection of three big ideas.**

There is a similar confusion that was noted from the responses given by teachers in their TSPCK tests on the component of curricular saliency. It was noted that teachers included pre-concepts and subordinate concepts under big ideas, an example of pre-concepts included are reaction rates and chemical reactions which are not appropriate to be big ideas. Most teachers suggested that Le-Chatelier's principle as a big idea, of which it is not, it is the subordinate concept when teaching chemical equilibrium. Figure 4.10 (above) and figure 4.11 (below) show the suggested big ideas of the two teachers whereby they mixed pre-concepts, subordinate concepts, and big ideas together.

2011 Response	2019 Response
1. Dynamic equilibrium 2. Equilibrium constant 3. Equilibrium shift	1. Rate of reaction 2. Lê Chateliers principle 3. Equilibrium constant

Figure 4. 11: **Teacher NMA4 2011 and 2019 response on selection of three big ideas**

The 2011 response in figure 4.10 above, reveal that teacher NMA4 suggested equilibrium shift is a big idea, even though, this is considered as the subordinate concept that is linked to another subordinate concept which is Le Chatelier's principle.

The other two suggested ideas; dynamic equilibrium and equilibrium constant are the big ideas (Mavhunga, 2012). In 2019 response, the same teacher suggested that the rate of reaction is one of the big ideas. That shows the confusion of big ideas in chemical equilibrium and the one in topic reaction kinetics. The rate of the reaction is considered as the topic taught within topic, reaction kinetics, and it can be classified as the topic needed to be taught before equilibrium can be introduced. Both teachers MPA5 and NMA4 mixed the big ideas and subordinate concepts in both of their responses. Below are teachers expanded knowledge on how they link their chosen big ideas and sub-concepts (see fig 4.11 below).

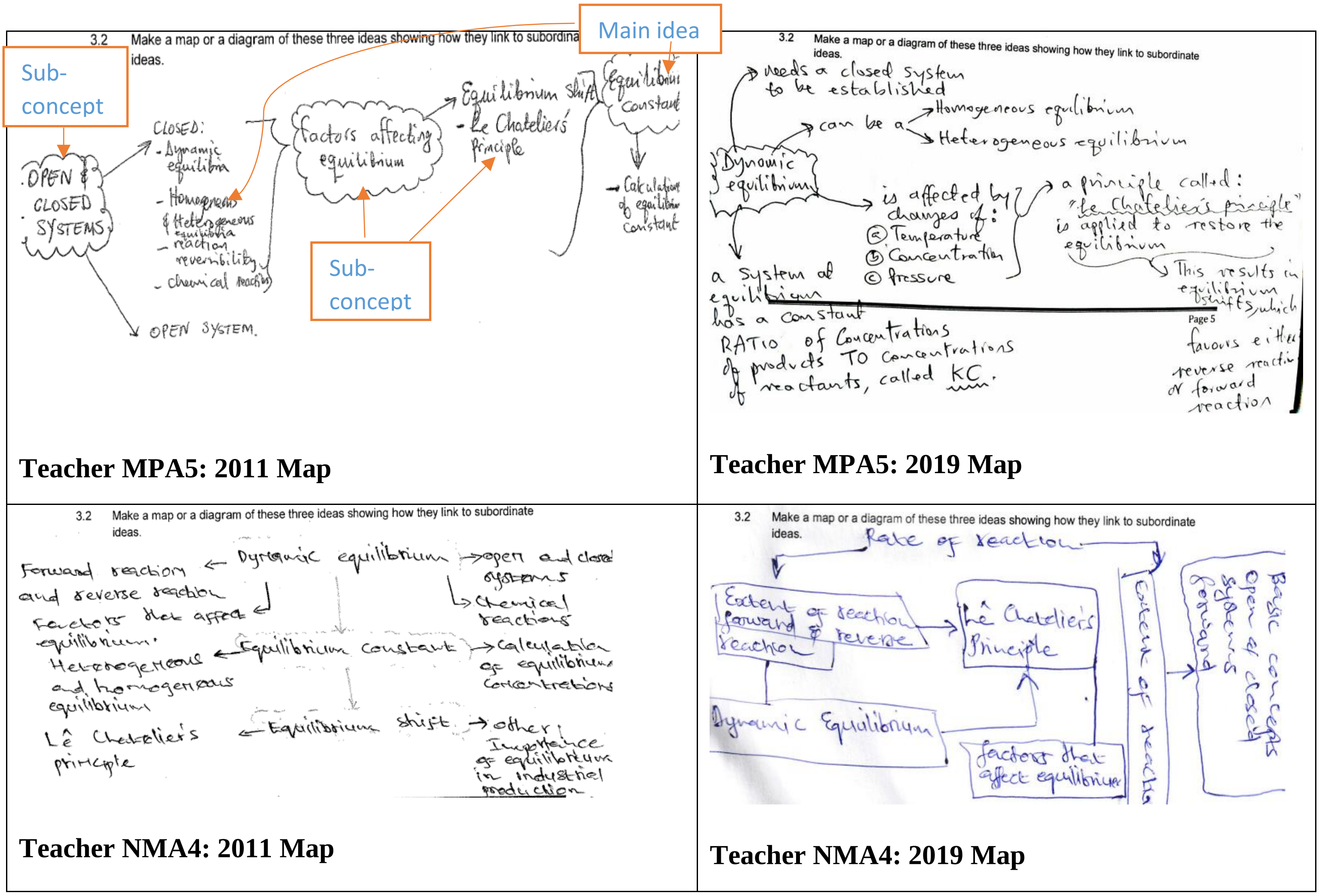
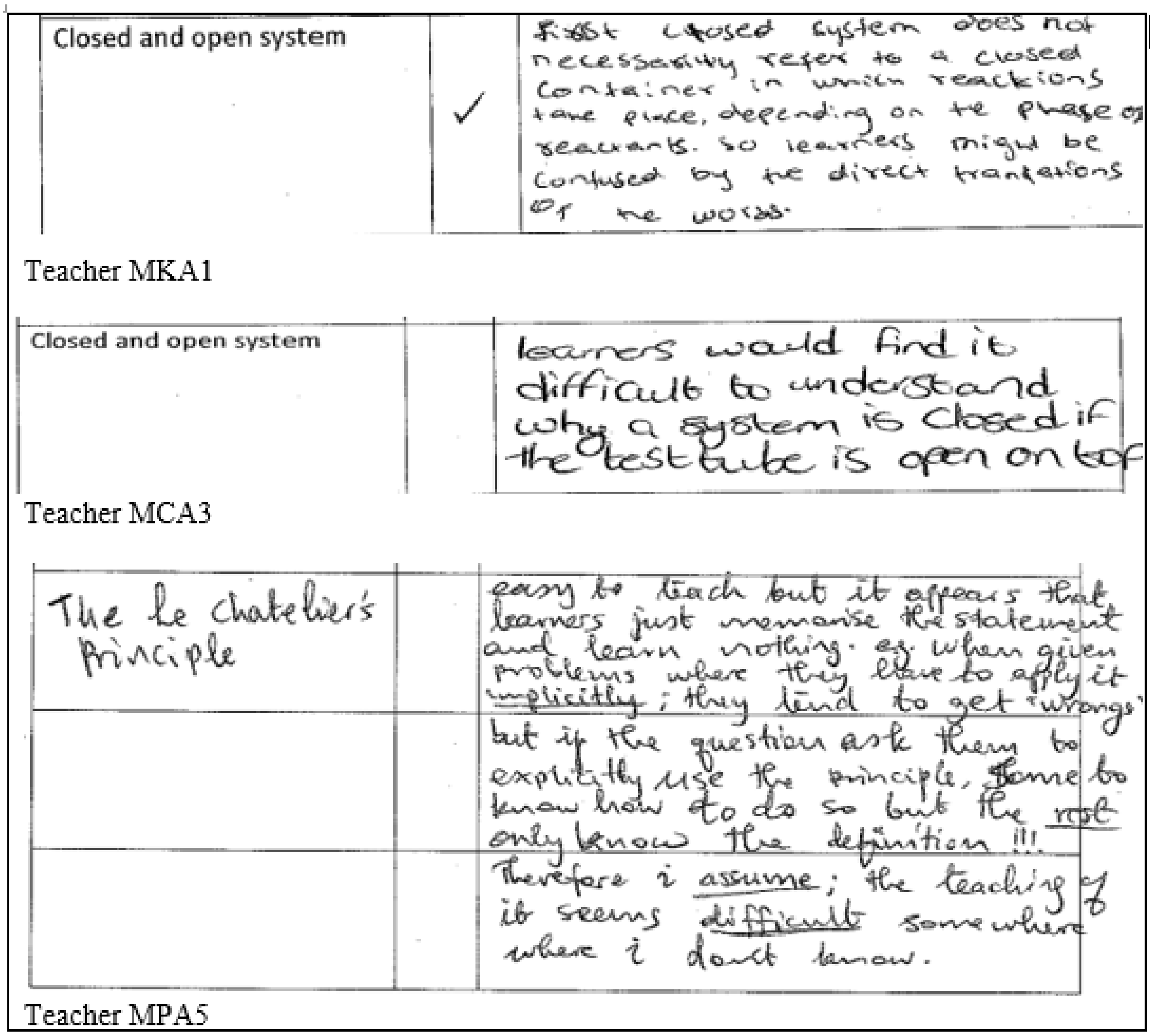


Figure 4. 12: **The pre (2011) and post (2019) Maps of both teacher MPA5 and NMA4**

The concept maps that the teachers drew showed inter-relation of big ideas and sub-concepts. Considering the 2011 concept maps of teacher MPA5 and MNA4, both teachers included chemical reaction in their concept maps which is pre-concept. It can form part of prior knowledge since the concept is taught in grade 10 physical science curriculum. In both 2011 concept maps, there is no clear linear evidence of development, and that indicated lack of coherence on how big ideas link to other sub-concepts. Teacher MPA5 showed improvement in the 2019 concept map, linear development is evident, there is a connection of ideas. The teacher identified the important concepts that are supposed to be covered when teaching the topic chemical equilibrium. Consequently, teacher NMA4 in the 2019 concept map included the reaction rate (pre-concept) which is basic to chemical equilibrium. However, the teacher was expected to provide explanatory notes to show the logic of the topics, and well-thought-out concept map.

4.3.4.3 Engaging on a component: What is difficult to teach.

This component was aimed at finding out the teacher knowledge about the concepts that are problematic in chemical equilibrium. Those are concepts that are difficult/challenging to teach or learn. Teachers were required to classify those ideas and to provide reasons why they consider them difficult. Also, they were supposed to provide a reason why they consider the identified topic(s) difficult. In this component teachers were widely given variety of facets on chemical equilibrium concepts, among these facets, they were to identify difficult ones. An extract in figure 4.13 below shows samples of 2011 teachers' responses from the TSPCK tool on a component WDT. Some teachers managed to identify aspects that they considered difficult to teach, however they did not provide reasons why they considered to teach. Most of the teachers considered the concept of open & closed system to be difficult to teach. The most common reason they gave is the issue of direct translation of everyday language to scientific language. For example, *closed system does not necessarily refer to a closed container…* the response given by teacher MKA1, also the reason given by teacher MCA3 reflects the language issue. Teacher MCA3 emphasised that *learners would find it difficult to understand why a system is closed if the test tube is open on top.*



Closed and open system	✓	First closed system does not necessarily refer to a closed container in which reactions take place, depending on the phase of reactants. So learners might be confused by the direct translations of the words.

Teacher MKA1

Closed and open system		learners would find it difficult to understand why a system is closed if the test tube is open on top

Teacher MCA3

The le chatelier's Principle		easy to teach but it appears that learners just memorise the statement and learn nothing. eg. when given problems where they have to apply it implicitly; they tend to get 'wrongs'
		but if the question ask them to explicitly use the principle, some to know how to do so but the rest only know the definition !!!
		Therefore i assume; the teaching of it seems difficult somewhere where i don't know.

Teacher MPA5

Figure 4. 13: **An extract of items tests from TSPCK tool on WDT for 2011.**

Teacher MPA5 identified the aspect of Le Chatelier's as one of the difficult concepts to teach, his explanation is not exactly presenting the main issue that makes the concept to be difficult to teach. He also seemed to be confused about what might cause the concept to be difficult to teach. In his explanation he said: *Therefore, I assume; the teaching of it seems difficult somewhere, where I do not know.* Similarly, teacher MPA5 in 2019 identified the *calculation of concentration using (RICE) ratio* as one of the concepts to be difficult to be taught. Also, here he seemed not to know exactly what the issue is, he mentioned that …*stoichiometry part is difficult to many learners.* This statement was also shared by teacher MLA2 in his explanation on the matter. The following is from teacher MLA2 …*stoichiometric calculations are sometimes a problem to learners (See fig 4.13 below)*.

The calculation of concentration using the (RICE) Ratio/ Initial/Concentration/Equilibrium Table	✓	the stoichiometry part is difficult to many learners!

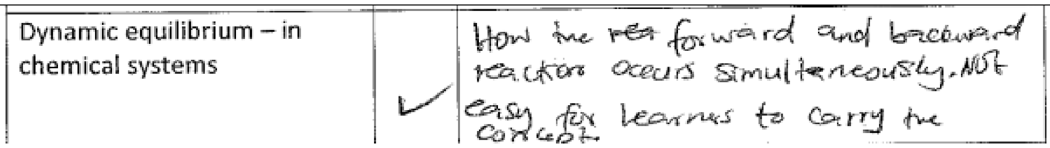
Teacher MPA5

The calculation of concentration using the (RICE) Ratio/ Initial/Concentration/Equilibrium Table	✓	Ratio and proportions as well as stochiometry calculations are sometimes a problem to the learners.

Teacher MLA2

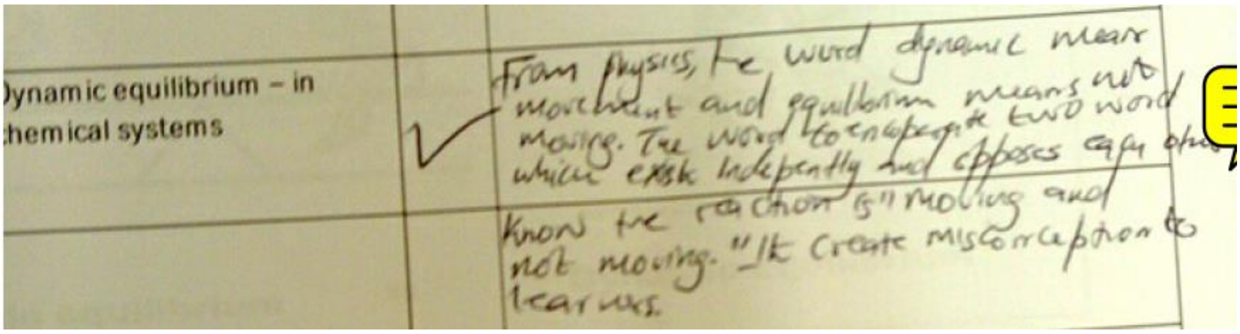
Figure 4. 14: **An extract of item tests from TSPCK tool on WDT 2019**

An extract below in figure 4.14 shows how teacher GNA7 responded on the component of WDT. The teacher identified dynamic equilibrium-in chemical systems as one of the difficult concepts to teach in both responses. The explanation he gave in the 2011 pre-test (in figure 4.13) was too basic compared to the 2019 post-test (figure 4.14) in which the teacher qualified developing level 3. Teacher GNA7 showed growth in the 2019 response. The teacher gave a thoughtful response whereby he affirmed that the difficulty of dynamic equilibrium arises with how the two words dynamic and equilibrium are used in physics. The teacher mentioned that *from physics, the word dynamic means movement and equilibrium means not moving…two words which exist independently and opposes each other…reaction is moving and not moving.* His explanation showed that there are some contradictions in physics and chemistry on how the two words dynamic and equilibrium are used. So, he further acknowledged that this creates a misconception to the learners. Generally, teachers succeeded to identify situations that are problematic about chemical equilibrium.



Dynamic equilibrium – in chemical systems	✓	How the forward and backward reaction occurs simultaneously. NOT easy for learners to carry the concept

2011 Response



Dynamic equilibrium – in chemical systems	✓	From physics, the word dynamic mean movement and equilibrium means not moving. The word to interpret two word which exist independently and opposes each other
		Know the reaction is "moving and not moving." It create misconception to learners.

2019 Response

Figure 4. 15: **Teacher GNA7's responses for both 2011 and 2019 on component WDT.**

The post response given above by teacher GNA7 affirms that the way terminologies are used in other learning areas (e.g. physics) might cause difficulties in learning other concepts in chemistry. For example, if the learner grasped the concept about equilibrium in physics that equilibrium means balance and dynamic means moving, equally that can be an advantage or disadvantage for learners learning about equilibrium in chemistry. Many common shared terms cause too many learning difficulties (Treagust and Bucat, 1999)

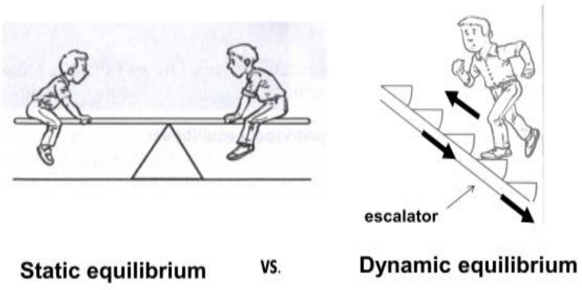
4.3.4.4 Engaging on the component: Representation

Given below is an extract from the TSPCK tool on component REP about dynamic and static equilibrium. Under this component, three possible representations/analogies/models for teaching static and dynamic equilibrium were given (see fig 4.16 below). Teachers were required to complete the table to indicate what they like and do not like about the representations. Secondly, teachers were required to choose the representation they like most and show how they would use it in the lesson. The core expectation is that the teachers should link their content knowledge to macroscopic or symbolic or sub-microscopic representation or the combination of the three representations in their teaching.

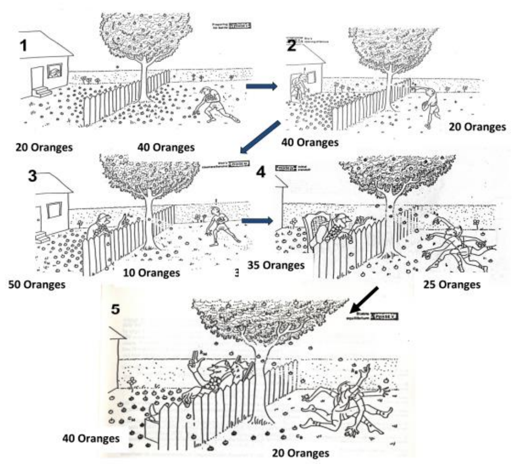
CATEGORY D: REPRESENTATIONS/ANALOGIES/MODELS

Dynamic and Static equilibrium

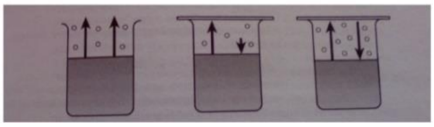
5. Below are possible representations/analogies/models for teaching the concept of stati versus dynamic equilibrium.



Representation 2



Representation 3



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

Representation No.	What I Like	What I do not like
1		
2		
3		

5.2 Which representation do you like most?

5.3 How would you use the representation that you like most?

Figure 4. 16: **An extract from TSPCK tool an item REP.**

2011 response	**2019 response**
5.2 Which representation do you like most? 3. 5.3 How would you use the representation that you like most? (1) To explain the concept of open & closed Systems. (2) To show that in a closed system, we have a reversibility of reactions UNLIKE at an open system where the reaction is one-directional. (3) i will therefore explain the issue of dynamic Equilibrium, by means of the Closed System. → that's it!!	5.2 Which representation do you like most? 1 5.3 How would you use the representation that you like most? i use the demonstration of the static equilibrium to teach dynamic equilibrium and consolidate it at the end with the escalator problem. 1st: i use kids of the same mass sitting at each end. Then; 2nd: Introduce a sandbag of a certain mass at one end and thus disturb the state of balance. 3rd: i ask learners what need to be done to regain a new state of balance etc. [NB: i tell them to play around the already existing mass of sand bag and not to add another mass!]

Figure 4. 17: **Teacher MPA5's response on component REP.**

Chemistry cannot be taught separately without analogies and models; teachers are required to be thoughtful when using multiple analogies and models in teaching chemical equilibrium. Teachers should be aware that their learners interpret models and analogies differently to such an extent that create difficulties in learning science concepts. The teacher must help learners to interpret and use analogies in a meaningful way to results in a significant gain (Harrison and Treagust, 2000a). Engaging on the response given by teacher MPA5 in figure 4.17 above, the teacher considered representation number 3 (see fig 4.17 2011 response), as the one he liked the most to be used in class when teaching the concept of static versus dynamic equilibrium. Representation number 3 is commonly used in many textbooks to introduce the concept of open and close system and dynamic equilibrium. Teacher MPA5 in the 2011 response acknowledged the three important concepts that he will address when using representation number 3, those concepts are close system, open system, and dynamic equilibrium. This showed an indication of teacher's ability to point out important concepts when equilibrium is introduced. However, the teacher did not indicate how he will use the representation in his lesson. In his explanation should have include three levels of representations (macroscopic, symbols and sub-microscopic) and how they link. The improved response of teacher MPA5 is evident in 2019 response. The teacher chose to use representation number one, whereby he started by using escalator to demonstrate the static and dynamic equilibrium. Secondly, the teacher considered using a seesaw demonstration as follows: *I use two kids of the same mass sitting at each end. Then, introduced a sandbag of a certain mass at one end and thus disturbed the state of balance. I ask learners what need to be done to regain a new state of balance.* The teacher explanation demonstrated an understanding of concepts of static and dynamic equilibrium. Using learners of the same mass can represent a state of balance or static, and whereas introducing a sandbag at first could mean non-static.

4.3.4.5 Engaging on Teaching Strategies

It was expected from teachers to come with teaching strategies that will close the gap on learners' prior knowledge about Le Chatelier's principle. The target was specifically about the effect of adding water to the reaction at equilibrium. The reaction is between water and acetic acid. Below is the figure 4.18 that presents a test item obtained from the TSPCK tool on the component of conceptual teaching strategies (CTS) where the teachers were required to provide a response on how they will go about teaching learners about the factors that are disturbing equilibrium.

CATEGORY E: TEACHING STRATEGIES

Le Châtelier's' Principle

6. Following below is a student's written response in a class test designed to assess prior knowledge of students about Le Châtelier's' Principle.

Question:

What is the effect of adding more water to reaction given below at equilibrium?

$$CH_3CO_2H(aq) + H_2O\,(l) \rightleftharpoons CH_3CO_2^-\,(aq) + H_3O^+(aq)$$

A student responded:

'More $CH_3CO_2^-$ (aq) and H_3O^+ (aq) will be formed, to counter act the effect of adding more water to the reactants. This will happen until a new equilibrium is reached'.

6.1 Following the student's response, how will you teach a lesson on predicting the effect of factors disturbing the equilibrium?

Figure 4. 18: **Test item on the component of TS from TSPCK tool.**

The averages in table 4.8 displayed that teachers showed most improvement on the component of teaching strategies with an average increase of 0.5. This was an indication that their teaching strategies had improved. It means the teachers found the item of TS easier in 2019 than in 2011. Comparing two responses given below (fig 4.18) of teacher KMA1, in 2011 response, the teacher wrote only the word 'introduction". We can assume that the teacher's knowledge on how to approach learner's prior knowledge was limited, since there is no evidence of acknowledgement of leaners' prior understanding. An improvement was observed in teacher's post response in 2019 as shown in figure 4.19 below.

2011 response	2019 response
6.1 Following the student's response, how will you teach a lesson on predicting the effect of factors disturbing the equilibrium? Introduction:	*6.1* Following the student's response, how will you teach a lesson on predicting the effect of factors disturbing the equilibrium? REP I will do practicals with them so that they can observe what happens to the equilibrium when a certain factor is added or introduced to disturb the equilibrium system and how the system counteract the disturbance. LC REP In this case I can even give an analogy of dissolving equal amounts of salt or sugar in different volumes which they do

	on a daily bases and let them tell me where the dissolution will occur rapidly.

Figure 4. 19: **An extract of the teacher KMA1 response on component TS.**

Teacher KMA1 response considered confrontation of learner's prior knowledge by suggesting that the use of practical work and analogy in her teaching to enhance understanding. Also, different components are acknowledged, namely curricular saliency and representations. In terms of curricular saliency in this case, the teacher KMA1 started by introducing factors by doing practical work so that learners can observe for themselves, this is the demonstration of Le-Chatelier's principle. However, the teacher did not show which factors she will be using to help learners to bridge the conceptual gap. Furthermore, teacher KMA1 introduced the macroscopic level of representation in her teaching, evidence is seen in her statement: *"…dissolving equal amounts of salt or sugar in different volumes…"* Another teacher, coded MSA6, in his teaching strategy considered approaching the learner misconception by introducing two types of levels of representations followed by explanations. The two representations the teacher acknowledged are symbolic (use of chemical formulas, equations and Kc expression) and sub-microscopic (drawing of balls/circles). The use of multiple representations is suggested to be one of the instructional strategies to overcome learning difficulties (Harrison & De Jong, 2005). In the response of teacher MSA6, important concepts about equilibrium are identified, for example equilibrium constant and equilibrium constant expression. However, there are few misconceptions that were evident in the teacher's response in the figure 4.20 below.

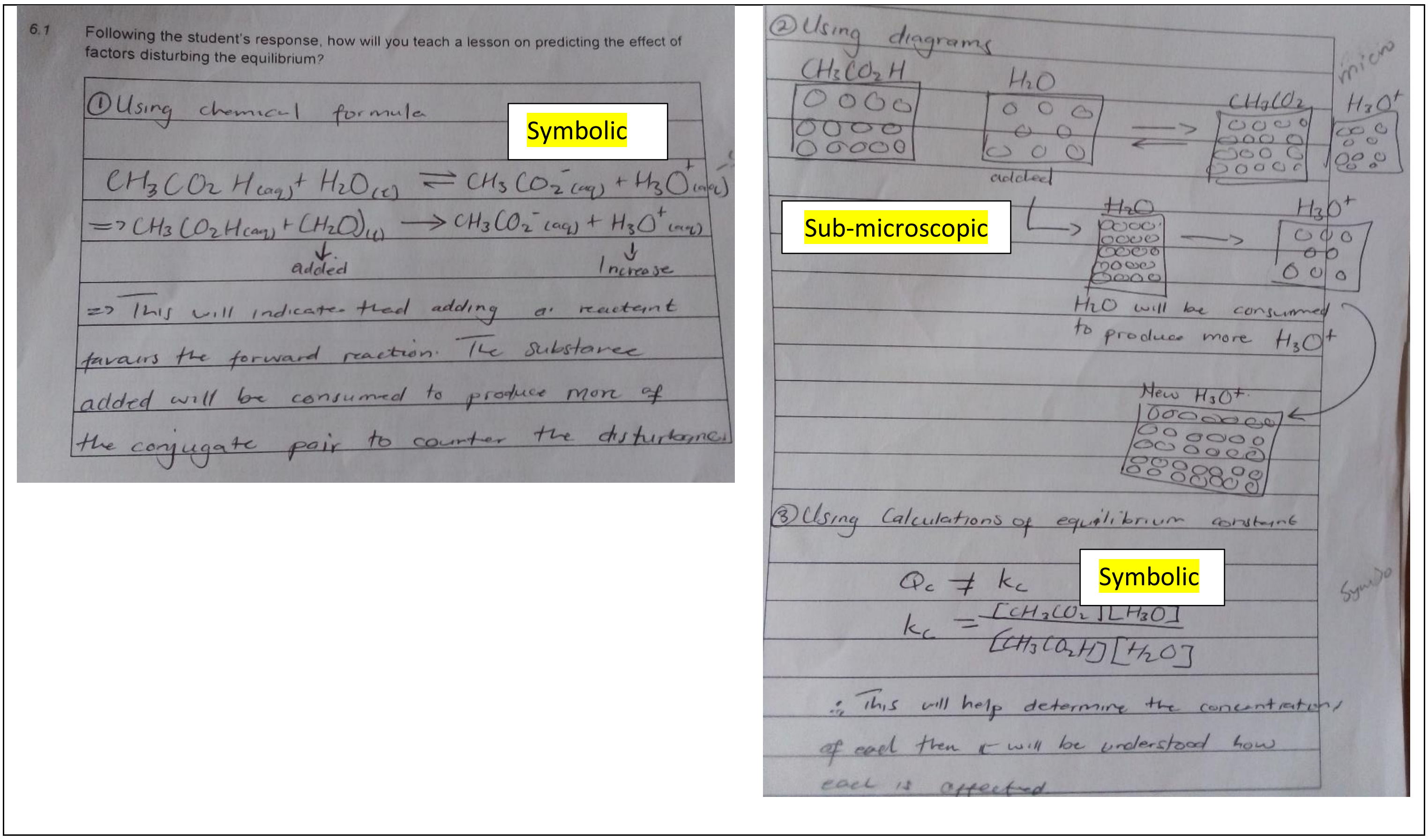


Figure 4. 20: **An extract of the teacher MSA6 response in 2019 on component TS**

The teacher indicated in his explanation that… *adding a reactant favours the forward reaction. The substance added will be consumed to produce more of the conjugate par to counter the disturbance*. From the response the teacher implied that addition of water to a weak acid dissolution disturbs the equilibrium, because adding water (reactant) will increase the H_30^+ ions, in return the products will produce the reactants. This showed that the teacher also had a misconception about equilibrium dissolution of weak acids, because weak acids do not dissociate further if more water is added. Like acetic acid is a weak acid, therefore its ability to dissociate it is limited, the addition of water will not dissociate more acetic acid, and therefore the equilibrium will not be affected. A similar misconception was observed in most teachers in the CK achievement test, most of the teachers believe that adding water to the weak acids will change the equilibrium.

4.4 Interview data analysis and findings

This section presents the analysis of the qualitative interviews data collected from all the seven teachers, by looking closely at teachers' perceived reasons for change in quality of topic specific PCK.

In chapter one the second research question was framed as follows: what are the physical science teachers' perceived reasons for the change or lack of change in the quality of TSPCK? To address the question, stimulated recall interviews together with semi-structured interviews were used to gather qualitative data. Stimulated recall interviews have no specific questions, interview questions emanate from the analysis of the responses in the topic specific PCK components items. Prior to the interviews data was collected using two tools, CK and TSPCK tests, these tests were administered as a take-home test for a certain period. Both CK and TSPCK tools were scored, analysed, and presented. Teachers were asked to elaborate on their responses they gave on selected components in the TSPCK instrument. Participants were given the opportunity to free up their minds about their experiences of teaching chemical equilibrium. Interviews were conducted to further find out the teachers' reasons on how they found the tests, and what might be the reasons for change or lack of changes in their performance in the chemical equilibrium topic-specific PCK tests.

During interviews, questions were asked about how participants found the items in the questionnaires, knowledge about chemical equilibrium, their experiences in teaching, and what could have benefited or limited them to develop their own CK and TSPCK. For their final interviews, semi-structured interviews were conducted, all teachers were interviewed about their self-perceived professional development. The table below shows a summary of the selected participants who were interviewed.

Table 4. 8: **Profiles of the participants**

Numbe r	Teacher code	QUALIFI-CATION(s)	Gender	Major subject	Teaching experienc e in years	Taught physical science and grade	TSPCK score (%)	
							2011	2019
1	KMA1	B.Ed.	F	Physical science	8	Yes (grade 10)	65	70
2	MLA2	B.Ed.	M	Physical science	8	Yes (grade 10 only)	45	65
3	MCA3	B.Ed.+ BScHon	M	Physical science	8	Yes	80	85
4	NMA4	B.Ed.+ HON(SE)	F	Physical science	8	No	75	60
5	MPA5	B.Ed. (Hon*)	M	Physical science	8	Yes (grade 12)	75	80
6	MSA6	B.Ed.+ Hon	M	Physical science	8	No	90	70
7	GNA7	B.Ed. + Hon (Math)	M	Physical science	8	No	50	60

4.5 Identifying teachers' perceived reasons

The interview transcripts were analysed using TA approach, whereby codes and themes were created, more details were discussed in chapter 3. The analysis of interview transcripts reflected repeated perceived reasons or events from different teachers that might have the influence on the quality of teachers' topic specific for the past 8 years' experience of teaching. From the reasons that were provided by teachers in the transcripts, important specific factors were coded, then grouped together to create themes. Codes with similar meanings were categorized. Repeated codes were listed and counted then their frequencies were recorded in a table.

Table 4. 9: **Important themes identified by teachers**

Significant events	**Frequencies**
Teaching experience	7
• Never taught grade 12	2
• Never taught the topic	2
• Taught the topic for past 7 years	2
• Lack of deep understanding of CK	2
• Better content knowledge	2
Teacher education	4
• University training	3
• Intervention	2
• Post graduate studies	4
Developmental programmes	5
• Workshops	5
• Lack of content training	4
• Content discussion	4
Teacher's own learning experiences	5
• Lack of marking experience	6
• Engaging the literature	2
School environment	3
• No parental support	2
• Poor administration	2
• Lack of resources	4

4.6 Findings

Below is the presentation of the findings from the interviews of the seven teachers. Five major themes were identified from teachers' transcripts.

Teaching experience

All teachers acknowledged teaching experience as an important factor in developing their content knowledge. Most teachers never taught the topic or grade 12 since they started their teaching career. It is the reason they experienced some challenges with content knowledge. Some teachers taught the topic throughout the past 8 years, it was important for them because they had better content knowledge and developed teaching strategies for teaching the topic.

Formal Teacher education

Four out of seven teachers pointed out formal teacher education as one of the important factors that play a role on teachers' content knowledge and topic specific PCK. Three teachers reflected on how they remembered some of the content knowledge and components of the topic specific-PCK from the intervention they attended during their university training. Some teachers who furthered their studies at honours level mentioned that the knowledge they acquired during course work was important. Theories about teaching and learning science were introduced to them during their honour's studies, so knowledge about learners' prior knowledge and teaching strategies were covered, and they were able to reflect on what they learned.

Developmental programmes

Five out of seven teachers identified workshops as significant. Some never attended workshops or content training since they are not teaching the subject and those who attended the workshops, they never shared knowledge and developments. So, that made them not have an improved understanding of the content knowledge, and the teaching part of using representations or analogies was also a challenge.

Teacher's own learning experiences

Three teachers mentioned that self-development is the key. For example, some mentioned that reading articles, journals, watching videos on You-tube website, watching other colleagues teaching and marking grade 12 external papers helped to develop a better understanding of the content knowledge, and sequencing of their teaching. Two teachers mentioned that they do not engage in discussions with colleagues nor have a content discussion within their department. That might impact them not to develop other alternative strategies for teaching the topic.

School environment

The school culture and environment can determine the level of effectiveness of a teacher. Two teachers mentioned that the school environment changed their effectiveness, they are no longer effective like in early years of teaching, and they lost interest in teaching. They mentioned the following reasons: there is no parental support, no support from the management and senior colleagues, they are on their own. Teachers always operate in isolation, the communication is lacking, and therefore it is hard for them to develop. Also, they are not coping with the level of stress that is caused by poor administration. Some teachers mentioned lack of resources at their schools is one of the factors that caused them to be ineffective in their teaching, and it difficult to come up with multiple strategies when teaching a lesson, so that forced them to use one strategy always.

4.6.1 KMA1

Teacher KMA1 has eight years of teaching experience. She majored in physical science during her education training at university. She started her career in 2013 as a grade 10 physical science teacher at a high school, and only taught physical science in grade 11 temporarily. Five years later she then became a natural science at a primary school. Teacher KMA1 go an extra mile to develop herself by engaging in discussion with high school science teachers, reading different physical science books, watch videos from on physics and chemistry topics and engage on other literature on different learning websites. Even though she is teaching natural science at primary school, but she has a passion for science and she even goes to the extent of helping high school learners with their assignments for physical science.

The reasons below were found from Teacher KMA1. First identified reason was related to LPK, she stated:

> *I found the concepts difficult; it was difficult to deal with learners' misconceptions, but I remembered some of the content,*

The second identified reason given by Teacher KMA1was based on teaching strategies (TS) of chemical equilibrium. She stated that the reason for lacking strategies of teaching the topic is because they never taught the topic during her experience of teaching. Eight years later she remembered the content knowledge on this topic from her university training, and that helped her to answer questions from both CK and TSPCK instruments. Her statement below supporting this is as follows:

I never taught the topic of chemical equilibrium. I only remembered…since I was taught the topic at university

Also, her experience of teaching grade 10 and 11 physical science for five years helped her to develop teaching strategies, even though she experienced some challenges with strategies for teaching chemical equilibrium since it is not taught in grades 10 and 11. She said:

The teaching part of the topic gave me a challenge, but I remembered the content, I never taught physical science grade 12. I never taught grade 12, I only taught grade 10 grade 11 physical science, I was only helping in grade 11 till 2017, currently I'm teaching at primary and it is quite boring to teach at primary school.

4.6.2 MLA2

Teacher MLA2 is a grade 10 physical science at high school in a rural area, and the school is under resource with no libraries and laboratories. He never taught physical science in grade 12 for the past eight years and never taught a topic chemical equilibrium since he completed his B.Ed. qualification in 2011. Teacher MLA2 never got involved in any educational programmes on the topic, also the sharing of content knowledge amongst colleagues.

Teacher MLA2 had a belief that if he attended development workshops, that might assist his development of content knowledge. He mentioned that, since he does not teach the content, so his content knowledge will stagnate. Below is the statement he made:

You know what, this side we do not attend workshops at all, we only attend the meetings. We do not discuss the content, we only talk about marksheets, work schedules and pacesetter that is it. We do not deal with content. Again neh! If you do not teach the topic you will not grow. That is why it was difficult for me to engage with those questions.

Another interesting statement teacher MLA2 gave is related to school contextual factors. He believes that the school environment or context plays a vital role in teachers' growth in content knowledge and pedagogical content knowledge. Below is the description that supports this.

I work at a school located at my village, and the environment is discouraging because there is no challenge, we do not share content knowledge, and the environment is not conducive for learning. Also, the resources are scarce. So as teachers we are not growing at all.

4.6.3 NMA4

Teacher NMA4 has also 8 years' teaching experience. She holds an honours degree in science education. She has taught mathematics at a high school throughout her experience of teaching. Teacher NMA4 never taught the physical science nor the topic chemical equilibrium in grade 12. She tried to engage in several kinds of literature about teaching and learning science during post-graduate studies. Also, she sometimes observed other colleagues teaching physical science but not the topic chemical equilibrium.

4.6.4 MPA5

Teacher MPA5 has taught physical science in grade 12 for the past 8 years of his teaching experience. He registered a Bachelor of Science Honours in Science but did not fulfil all graduation requirements since he only did the course work components and left out the research section of the degree. Then did a few courses on teaching and learning science. Throughout his teaching experience, he never participated in marking the external end of the year physical science papers for grade 12.

The component teaching strategy (TS) appeared to be most difficult for most of the teachers. Teacher MPA5 did not show any shift on the component TS. He attributed his lack of teaching strategies to many factors. He mentioned that they are not developed, and chemistry topics are not given much attention during their content workshops. Regardless of his lack of change in the component TS, his content knowledge about the topic reflected to be good. Teaching the topic in grade 12 assisted him to have better content knowledge in 2019 CK-tests than in the 2011 ones. During his telephonic interview, the following statement was given by teacher MPA5:

> *I teach grade 12 physical sciences, and it marked 8 years now, that helped me to develop better content knowledge…. But I lack strategies to apply when teaching science. I have lot of misconceptions about the topic, I do not develop myself and that causes problem in class. Again, we are not developed thus contribute to poor results. I attended few workshops, but we discussed Newton's laws and some parts of organic chemistry. Our curriculum advisor does too much physics content than chemistry, I do not remember doing chemical equilibrium at workshops. Often, curriculum advisors talk less about content, they only talk about exam guidelines and CAPS policy. But I think I need to develop myself.*

Teacher MPA5 believed that self-development is key, if not done it causes problems in class. Considering the interview response from teacher MPA5, it seems teachers' developmental workshops are minimal, thus his teaching strategies and approach towards learners' misconceptions are lacking. The teaching approach the teacher MPA5 was using for the past eight years is not changing, his knowledge of addressing misconceptions still a problem. Teacher MPA5 mentioned that he teaches physical science like mathematics. He said:

> *…but the difficult part was on how to approach learner's misconceptions. Addressing learners' misconceptions was a problem. Also, the use of analogies in teaching, not easy to associates these analogies with content knowledge. I teach physical science like I teach mathematics; I do more calculations; I work with numbers a lot. I feel like I'm teaching mathematics not science.*

Like other teachers who were interviewed, teacher MPA5 acknowledged that sharing of content with colleagues who teaches the same subject is an important factor that contributes to knowledge growth. He further mentioned that he does not prepare the lessons, and he never marked national senior certificate external papers for grade 12, and that might be contributing factors to the lack of content knowledge and teaching strategies. Below is an extract from teacher MPA5's transcript:

> *Sharing content knowledge with colleagues who are teaching the same subject is important. But here at my school we operate in isolation, we do not communicate. If we can talk more often, is the more we will understand better. So here we teach same subject, same grade but we do not discuss lesson or content. I do not prepare lesson; I watch a person teaching on YouTube videos then go to teach with the same knowledge acquired from the video. Another, contributing factor is that I never went for marking, if maybe I went to marking before I was going to learn something. Maybe my content and teaching strategies were going to develop.*

4.6.5 MSA6

Teacher MSA6 has eight years' teaching experience, and honours in leadership and management. He majored in physical science in his first Bachelor of Education qualification. He started on his teaching post as a mathematics teacher, and became a head of department, heading mathematics department at a school. Teacher MSA6 never taught physical science over the past eight years, last time he taught the topic chemical equilibrium was in 2011 during his teacher training at university. His interest is in leadership and management, he lost passion for physical science and his content knowledge for teaching chemical equilibrium is limited, and the quality of the teacher's topic-specific PCK is also poor.

Teacher MSA6 performed less in the 2019 TSPCK test compared to the 2011 tests. He found the questions very difficult to answer. The identified reasons for less performance are attributed to a lack of content knowledge and teaching strategies (TS) and not teaching physical science in grade 12. Below are the reasons given by teacher MSA6.

> *Questions were based on my knowledge of physical science teaching; they were difficult for me to answer, they were little bit challenging to answer. They were based on content knowledge and pedagogy. So, I had to sit down and think deeply. Questions needed a clear mind. Eish, the teaching part of it was difficult. The thing is that I never taught science, I only taught physical science for a year in grade 10. I forgot the content and strategies of teaching the topic.*

4.7 Conclusion

This chapter presented the analysis of the data collected in the study. Both quantitative and qualitative analysis was done here. The intention of this analysis was to find answers to the research questions of the study that were presented in chapter one. The findings of the study were presented. Generally, averages in table 4.8 revealed that teachers showed improvement on the component LPK. The item maps also revealed that teachers found items on this component easy, LPK was however, the secondary component found easy after CS which was the first component. However, an intensive look on the individuals difficulties performances revealed that out of seven teachers, three showed level improvement (their scores increased), two had declines (their scores decreased) and the remaining two teachers showed no shift in their scores as they remained in level 3, which is exemplary.

Findings on the analysis of the 2011 and 2019 CK tests revealed that the change in teachers' content knowledge over the period of eight years was not satisfactory. Their overall performance increased slightly, however; some teachers showed a decline in 2019 CK post-tests. The findings on the TSPCK-tests revealed that teachers found two components (LPK and CS) difficult when comparing TSPCK test results of 2019 with those of 2011. There was no change in the component WDT. On the two components REP and TS there was an average increase. The lack of improvement in both CK and TSPCK can be attributed to many factors, which are discussed later. The next chapter presents the general discussion and conclusion on the findings.

5. CHAPTER FIVE: DISCUSSION

This chapter, firstly, it presents the discussion of all findings and how these findings are relevant to the literature presented in chapter two, secondly, the conclusion of the study by summarizing answers to the research questions. Finally, the limitations, recommendations, and reflections are discussed.

5.1 Introduction

This study was established to find out the influence of experience on the quality of teachers' topic-specific pedagogical content knowledge (TSPCK) for teaching chemical equilibrium. The mixed-methods approach was used. Two validated measuring instruments were administered to seven physical science teachers. The same teachers were invited to take part in the interviews, however only five willingly took part. The findings of the analysis of teachers' responses to the use instruments were analysed and presented separately from teachers' responses to the interviews in Chapter Four and Chapter Five, respectively. The analysis focused between two points, the 2011 and 2019 instruments (both CK and TSPCK tests) were compared. The analysis of the teachers' responses to the 2011 and 2019 TSPCK instruments using five components of TSPCK model showed the manifestations of teachers' CK and how teachers transform their CK when teaching chemical equilibrium. Many factors that were found to be contributed to the performance of teachers in the CK and TSPCK tests were also identified. Teachers' perceived reasons for change or lack of change in the quality of topic-specific pedagogical content knowledge for teaching equilibrium were presented.

5.2 Findings from the study

This study was guided by the following main research question and two sub-questions:

What is the influence of the experience on the quality of teachers' TSPCK in teaching chemical equilibrium?

1. What is the quality of teachers TSPCK and CK in teaching chemical equilibrium after 8 years of completing B.Ed.?
2. What are the physical science teachers' perceived reasons for the change or lack of change in the quality of TSPCK?

The rubric was used for scoring of teachers' responses to the CK and TSPCK instruments. The tests results were put under Rasch measurement model to compare teachers' performances in 2011 and 2019 tests. The quantitative analysis of the teachers' responses to the CK and TSPCK instruments revealed three factors that influenced teachers' quality of

TSPCK. Factors are the level of teachers' content knowledge, the experience of teaching the topic, and the level of teachers' qualifications.

Further, qualitative analysis was done to compare teachers' responses to the 2011 and 2019 TSPCK instruments, the following was revealed about the teachers' performance on the test:

- Teachers who taught physical science in grade 12 for the period of eight years showed significant improvement in their content knowledge
- Teachers, not all, who exhibited an improved level of content knowledge displayed the ability to identify situations that are problematic about chemical equilibrium.
- Teachers revealed significant improvement on the component LPK over a period of eight years.
- Teachers who never taught grade 12 at all over the period of eight years showed shortcomings in the knowledge about alternative conceptions of the learners
- Teachers who had honours qualifications in science education showed improvement in the level of quality of TSPCK.

The analysis of the interview transcripts of the five teachers who participated in the interviews revealed the following significant events.

- Teaching experience
- Formal Teacher education
- Developmental programmes
- Teacher's own learning experiences
- School environment

5.3 Discussion of the findings

5.3.1 Teaching experience

The analysis of the items presented in chapter 5 and prompts from the interviews revealed that two teachers who taught the topic in grade 12 for the period of eight years had high level of improvement in the TSPCK test scores. They had good CK and good TSPCK. There were two (KMA1 and NMA4) teachers with improved content knowledge but who never taught the topic in grade 12 at all over the period of eight years. A qualitative analysis of their responses to the TSPCK instrument revealed that similar teachers were found with no improvement on the following components: curricular saliency, learner prior knowledge, and representations. Teachers (KMA1 and NMA4) had difficulties in the following: choosing and sequencing the concepts; identifying and addressing learners' misconceptions; and the use of representations in the topic. As a result, their quality of TSPCK did not improve. This is an indication that for the teachers 'quality of TSPCK to grow, teachers must teach the topic to the learners. But first teachers must have good content knowledge about the subject (Shulman, 1986). Grossman (1990) argued that one of the important factors in developing teacher pedagogical content knowledge is teaching experience. Also, teachers' pedagogical content knowledge grows when teachers are engaging the content knowledge in teaching practices (Lederman, Gess-Newsome & Latz, 1994). However, some teachers even though they had improved content knowledge but still lacked in their teaching strategies due to having no teaching practice of the topic. This was not the case when looking at those who were experienced in teaching the topic, since their content knowledge about learners' prior knowledge, sequencing the topic, and strategies were improved. Science teachers' PCK grows when there is constant use of content knowledge in teaching practices (Schneider, 2019). This means teachers' quality of TSPCK also develops when the teacher is actively teaching the topic.

5.3.2 Formal Teacher education

Only two teachers had an honours qualification in science education, and one teacher, MPA5, only completed some of the course work in science education. All these three teachers showed improvement in their CK and TSPCK test scores. All three teachers were interviewed, and they all mentioned doing postgraduate studies in physics and chemistry as important for the development of their content knowledge. Postgraduate studies provided these teachers with solid content knowledge of physics and chemistry, and they had developed quality of TSPCK, they were able to transform CK. According to Mavhunga (2014), transformation of CK (TSPCK) emanates from understanding CK.

The other two teachers, GNA7 and MSA6, had honours qualifications that are not related to science education. One, GNA7, had honours in mathematics, and teacher MSA6 had honours in Management and Leadership. These two teachers did not show a decline in their CK test scores, and the TSPCK scores were below the mean scores in 2019, only teacher MSA6 exhibited decline TSPCK scores. Teacher MSA6 showed no score improvement in these two components WDT and TS, the scores decline was observed in the following components LPK, CS and REP. Teacher GNA7 showed no improvement in the following components LPK and CS. These teachers were also interviewed, they mentioned that they were relying on the undergraduate content knowledge they acquired during their undergraduate training to answer the tests questions. Also, they mentioned, they do not remember most of the content knowledge about chemical equilibrium since they never taught the topic over period of eight years. This is the reason why many studies highlighted the importance of CK in teaching, because, without the CK, a teacher cannot develop PCK.

5.3.3 Developmental programmes

Teacher developmental programmes play a crucial role in supporting teachers' growth of TSPCK, more importantly when teachers are actively involved in content discussions. In chapter four it was found that out of three of five teachers who were not attending any form of workshops or content training showed decline in their CK test scores. Whereas the other two showed improvement in their CK scores but still performed below their mean scores. An analysis of interview transcripts revealed that all five teachers did not teach grade 12, but the two who were identified with improved CK scores, took part in helping the grade 12 learners during extra-classes. Teachers perceived reasons for lack of improvement were given as follows: they were not attending content training, they attended meetings only that focus on general knowledge and never discussed the content knowledge.

Even though some teachers showed improvement in their CK, but they were unable to identify the possible misconceptions in learners' responses. They had difficulties to draw on their content knowledge when it came to addressing learners' preconception. This an indication that content alone is not enough to contribute to the knowledge and skills for transforming a topic. According to Schneider (2019), over time, teachers develop specialised knowledge and skills for teaching science because they are practically exposed to learning programmes, and experiences, classroom situations and learners. In chapter two, it was discussed that teachers' CK and PCK develops if teachers are offered support over their teaching career from pre-service teachers to the well experienced (Carlson & Daehler, 2019). It means, teachers need to learn continuously, by attending learning development programmes, that provide support to their CK and PCK. Through continuous developmental programmes and teaching practice, teachers develop the capability to transform science topics.

5.3.4 Teacher's own learning experiences

As it was discussed in chapter 5 that self-development can play a crucial role in adding value to teachers' development of TSPCK, more especially when teachers engage themselves in reading articles and journals about teaching and learning science. Furthermore, teachers can help themselves to grow their PCK by watching each other when presenting the lessons in the classroom, or novice teachers can observe expert teachers' lessons.

This is supported by Mavhunga (2019) when she stated that both pre-service and in-service learners owe to develop their knowledge by engaging experts in the field. She further argued that this shared expert knowledge may arise from various sources such as coursework, journals or publications and structured programs focusing on learning and teaching science topics (Mavhunga, 2019).

Daily planning of the lessons, teaching lessons, and lesson reflections (Sorge, Neumann & Stender, 2019), also played a role in teachers' knowledge. Teacher MPA5 revealed that he grows his CK through watching content from sources such as You-tube website and, teachers' engagements before he teaches. He also mentioned that marking grade 12 learners' external papers allow him exposure to identify, understand and address alternative learners' conceptions

5.3.5 School environment

Two teachers mentioned some aspects that are closely linked to schools' environments. The following aspects were identified: the lack of support from management and experienced colleagues, lack of parental support at school, poor administration, and lack of resources. Also, they mentioned that the environment they teach in is not conducive for learning, and it is discouraging. Similar teachers never had any exposure to teaching the topic in grade 12. It was found that these teachers' quality of TSPCK was not improved after eight years, as a result, these teachers found it difficult to use five knowledge components interactively. Due to that, their level of quality of TSPCK was negatively affected. Mavhunga and Rollnick (2013) state that quality TSPCK is defined as the teachers' ability to use knowledge components interactively to transform their CK in a way that is easily accessible to learners.

5.4 Summary of findings

Several factors or reasons that were presented by teachers in the interviews are a cause for concern on why quality of topic-specific PCK of some teachers did not improve. The discussion above provided evidence that **experience has an influence** on the quality of teachers' TSPCK. Some teachers understanding of chemical equilibrium and their knowledge of transforming the content for the purpose of teaching was affected by the following factors, **the lack of chemistry knowledge**, **lack of attending education modules**, **lack of content discussion** or

collaborations amongst colleagues, and **lack of attending developmental trainings**. Including all the above, it was also discovered that most teachers were **found not teaching the topic in grade 12**. A few of those who were teaching physical science were found to have the good content knowledge and reasonable quality of TSPCK.

Science teachers' PCK grows when there is constant use of content knowledge in teaching practices (Schneider, 2019). However, teaching content knowledge or a subject matter knowledge is not enough. Teachers should get involved in sharing content with each other, attending educational programmes, and doing extra courses in line with the subject matter.

Teaching a topic requires enough subject matter and knowledge about learners' misconceptions. Teachers should do more efforts to find out as much as possible about their learners' capabilities before presenting any science lesson to learners (Bishop & Denley, 2007). Learners' capabilities refer to learners' cognitive thinking, learner's pre-instructional knowledge or believes that teachers build on when presenting a lesson. PCK builds on the foundation of understanding learners' needs when teaching and planning the lesson (Geddis, Onslow, Beynon, & Oesch, 1993). This means teachers' PCK develops when teaching and reflecting on the lesson is done. It is difficult for a teacher to grow content knowledge and strategies for subject matter that he or she never taught.

5.5 Answering the research questions

The aim of the study was to examine the influence of the experience on the quality of teachers' TSPCK in teaching chemical equilibrium. This section presents the research findings and attempts to answer the research questions. Two sub-questions questions were asked in the study, first, the two questions will be answered then followed by answering the major research question.

Research question 1: In chapter one, the first research question that was asked is as follows: **What is the quality of teachers TSPCK and CK in teaching chemical equilibrium after 8 years of completing B.Ed.?** This question search for knowledge on how teachers used the components of TSPCK to transform a topic equilibrium. To answer the first research question, firstly the quantitative analysis was done on the CK tests, the 2011 CK test scores were compared with the 2019 CK test scores. Secondly, both intensive quantitative and qualitative analysis were done on each of the five TSPCK components. The five components identified: learner's prior knowledge, curricular saliency, what is difficult to teach, representation and teaching strategies. Miscoceptions were observed in most teachers in the CK achievement test, most of the teachers believe that adding water to the weak acids will change the equilibrium. Not only learners who find the concepts stoichiometry difficult, also teachers were observed to have misunderstandings.

Teachers' responses to the 2011 tests and 2019 tests were compared. It was found that some teachers, even after 8 years in their teaching, typically lacked sound content knowledge, therefore, their topic-specific PCK appeared to be inadequate and low when it comes to teaching chemical equilibrium. Despite the overall little increase on the quality of the TSPCK of the teachers, there were some components where there was no shift and a decline was observed. Below is the summary of findings from each component:

- **Curricular Saliency**

In this item the decline was observed, even so, most teachers find the items on this component easiest. Teachers were found to have confusion with big ideas and subordinate ideas. They were mixing big ideas with sub-ordinate concepts.

- **Learners' Prior Knowledge**

It was found to be the component that teachers showed the decline in terms of performance scores. Teachers found this item difficult in the 2019 TSPCK tests, compared to the ones in the year 2011. Most teachers were found to have misconceptions, and their knowledge for addressing learners’ misconceptions was lacking.

- **What is difficult or easy to teach?**

Generally, there was no average increase on this component, but that does not mean there was no knowledge improvement of individuals. It was found to be the second most difficult item.

- **Teaching strategies**

The average increase was observed on this component, but the individual analysis showed that teachers found items on this component to be most difficult. Some teachers showed to be lacking conceptual teaching strategies to teach chemical equilibrium.

- **Representations**

On this component, teachers found the items easier. The improvement was observed. It appeared to be the second most component to be easy. Some teachers showed to be more knowledgeable on the use of three levels of representations (macroscopic, symbolic, and sub-microscopic) in teaching the topic.

Research question 2: The second research question that was asked is: **What are the physical science teachers' perceived reasons for the change or lack of change in the quality of TSPCK?** This question was about getting an understanding of the experiences that teachers were exposed to throughout their teaching career over eight years. Post-CK Tests (I refer to 2019 CK tests) revealed that their content knowledge is not satisfactory, results showed a decline from 2011 CK-test scores, and TSPCK tests revealed that their PCK at topic level remained low, even though there was a little increase. Based on these results interviews conducted with five teachers through telephone to understand the changes or lack of changes observed across the content knowledge and topic-specific PCK test scores, the following two major findings were presented, (1) after 8 years of experience teachers’ content knowledge is still lacking; (2) teachers’ quality of TSPCK is not satisfactory. Interviews revealed the following reasons from teachers. Firstly, five teachers were found not teaching physical science in grade 12, and they never taught the topic chemical equilibrium over a period of 8 years. Secondly, they were not exposed to the topic in any developmental programmes they attended since they started to teach. Thirdly, they also do not develop themselves through engaging with other colleagues.

5.6 Conclusion and Recommendations

The study was intended to find out the influence of experience on the quality of teachers' TSPCK in a topic chemical equilibrium. Two questions that were asked in this study were answered above. Based on the findings regarding the first question, experience had an influence on the quality of TSPCK of the teachers. There were numerous factors that contributed to the poor and good quality of teachers TSPCK. The major identified factor towards the growth or good quality of TSPCK of the teachers is the experience of teaching the topic chemical equilibrium. The findings from this study revealed that there is a lack of competence of the teachers on the use of topic-specific PCK components within the topic chemical equilibrium. It was found that in most teachers, the content knowledge and ability to transform it to the learners was not satisfactory. These teachers were once exposed to intervention in the final year of their study. The intervention involved developing their content knowledge and the use of five TSPCK components in teaching within the topic, chemical equilibrium. During that time their topic-specific PCK was reasonable (Mavhunga, 2012). Currently, these teachers have eight years of experience in the field of education, teaching different subjects at different schools. It was noted that most of these teachers never taught physical science during their eight years of experience. Those teachers who never taught physical science or the topic chemical equilibrium experienced a lack of improvement on the quality of their TSPCK, and some had a decline. The major reason for the decline or no improvement is because they do not teach or did not teach the subject throughout their teaching experience. For the TSPCK to develop, teachers are required to obtain knowledge of learners' perceptions and difficulties in teaching and learning when engaging the topic. Grossman (1990) states that teaching experience is a crucial factor in the development of PCK. Lederman, Gess-Newsome & Latz (1994) in their studies engaging pre-service teachers found that PCK grows when engaging the content matter knowledge in teaching practices. In this study, it was found that teachers who are not teaching grade 12 their quality of TSPCK did not improve, because the topic chemical equilibrium is taught in grade 12. The study also revealed that teachers lack awareness about learners' prior knowledge, learning difficulties, and conceptual teaching strategies within the topic, chemical equilibrium. Teachers may develop their knowledge about learners' preconceptions from studying a topic in education science courses and by discussing and comparing these preconceptions relative to their own conceptions (Geddis, 1993).

5.7 Limitations of the study

Initially, the study proposed to involve the sample size of 10 in-service teachers, however, 3 of them dropped along the way due to their unknown personal reasons. I noted that the proposed sample size of the study was small, so it was difficult for the researcher to make generalisations. There are two reasons that forced the researcher to consider using only sample size (N=7), the first reason is that only teachers who were easily accessible were considered. The second reason was teachers who showed interest voluntarily were also considered to take part in the study. Regardless of the small sample size, the findings that emerged in this might add significantly to the existing literature. The second limitation was that few teachers did not attempt some of the items within a component, they left blank spaces, so it was difficult for the researcher to make a conclusion about their understanding of those unanswered items. However, the assumption was made that they do not know how to respond to those items. The third limitation was that teachers were assessed on how to use five TSPCK components based on planning context, whether they were observed on their understanding on transformation of both CK and PCK and TSPCK on a topic equilibrium. The fourth limitation is that telephonic interviews are difficult to conduct because of poor network connections in areas where participants are based.

5.8 Recommendations for future research

Future researchers should take the limitations of this study into consideration when a similar study is conducted. Firstly, the researchers should consider using a bigger sample size so that they will be able to make generalisation easily. Secondly, researchers should continue to follow teachers to examine their PCK after a few years of leaving university, not only in the planning context also in actual teaching. Teachers in the field of education should be constantly developed, and interventions on equipping teachers on five TSPCK components should take place. Intervention might help teachers to be able to reason better, and reasoning of content through the five components produces knowledge for teaching that is specific to the topic (Mavhunga & Rollnick, 2013). If a research methodology includes telephonic interviews, the researcher should do proper planning before a telephonic interview and prepares participants on time about the actual interview so that the participants can be in a place with a good internet connection.

5.9 Reflections

This study intended to find out how experience influences the quality of teachers' topic-specific TSPCK within the topic chemical equilibrium. I collected data from seven teachers using two tools which are the CK and TSPCK tools for chemical equilibrium, and the interviews. The first tool (CK) was used to collect data on the teacher's content knowledge, and the second tool (TSPCK) was used to collect data from teachers, the tool consisted of five components of

TSPCK that are used for chemical equilibrium. Finally, interviews were used to get a deeper understanding of teachers' experiences in the field of teaching. The scoring of the teachers' responses was done using a memo and rubric (Mavhunga, 2012). The purpose of scoring their responses was to quantify teachers' responses so that generalisations can be made. Upon completion of scoring the data, an analysis was completed, then results were presented. Afterwards, interviews were conducted guided by the score's teachers obtained. At first, I was nervous, I did not know on how I am going to approach my interviewees because it was my first time doing the interviews. It is important for the interviewer to start interviews by involving the interviewees in quick talks, jokes, and kindness (Shuy, 2003). These engagements provide a room to break the ice and maintain a friendly conversation. For me it is always difficult to make jokes or coming up with small talks, I had to ask for advice from other people who conducted interviews before, and that assisted me a lot to conduct my interviews successfully.

The influence of experience on the quality of TSPCK in a topic is the focus in this study. Two tools and the interviews as discussed above were used to gather the data. The prompts from both CK and TSPCK tools, as well as interviews, made it possible for me to answer the research questions of this study. Even though I found it difficult to collect data as per allocated time, this was due to delays I experienced from some of the participants who took more than the time given to respond to the tool, since the first methods used was emails.

Telephone interviews were also not easy to conduct because listening and taking down notes simultaneously was never easy. The challenge is that you might miss taking notes of important information. It required the researcher to be faster. Another factor was that to analyse the interview data was not easy, since it was my first-time experience doing interviews analysis. It was not easy for me to choose what to include or what to leave out from the interview prompts. I had to categorize the prompts from the interviews. Prior analysis, a colleague was invited to generate a component of the prompts, that was done independently and without the knowledge of the researcher's component prompts. The aim was to avoid bias, also to encourage the validity of the component prompts. Thereafter the analysis was done accurately without any form of manipulation.

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Appendices

Appendix 1: Ethics clearance certificate

WITS SCHOOL OF EDUCATION

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

SCHOOL OF EDUCATION ETHICS COMMITTEE
CONSTITUTED UNDER THE UNIVERSITY HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: 2019ECE038M**
PROJECT TITLE	The Influence of Experience on Teacher Topic Specific PCK (TSPCK) on Chemical Equilibrium
INVESTIGATOR	Mongoatse Teffo
SCHOOL/DEPARTMENT OF INVESTIGATOR	WITS SCHOOL OF EDUCATION
DATE CONSIDERED	12 September 2019
DECISION OF THE COMMITTEE	Approved unconditionally
EXPIRY DATE	Date of submission of the project report

ISSUE DATE OF CERTIFICATE 13 September 2019 **CHAIRPERSON** (Dr. Paul Goldschagg)

cc: Supervisor: Dr. Mpho Mosabala

DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** emailed to the Ethics Office: Matsie.Mabeta@wits.ac.za .

I fully understand the conditions under which I am authorized to carry out the abovementioned research and I guarantee to ensure compliance with these conditions. Should any departure be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

______________________ **Signature**

_____/_____/_____ **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix 2: **The Participants consent form**

Participants consent form

University of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg SA

t+27 11 7173414 f+27 11 7173259

ME.d Student: Peter Mongoatse Te

Student No.: 3202

mongoatse@gmail.c

PARTICIPATING IN-SERVICE TEACHER INVITATION LETTER

DATE: 28 JUNE 2019

Dear In-service teacher

My name Mongoatse Peter Teffo and I am a ME.d student in the School of Education at tl University of the Witwatersrand South Africa.

I am doing research on topic specific pedagogical content knowledge (TSPCK) of in-serv teachers in Chemical equilibrium. TSPCK is the specific way in which teachers make students understand the content being taught in a specific topic. When we look at the ex results from the past few years, Chemical equilibrium has been identified as one of the probl areas and therefore we decided to make the topic of my study

My research involves exploring the TSPCK as well as the content knowledge for teaching chemical equilibrium.

I was wondering whether you would mind completing the two tests below and returning it me as soon as possible. Please make sure that you set aside enough time to complete them one sitting as the time taken for you to complete the documents is also important to me.

1 Topic Specific PCK tool

2 Content knowledge tool

Your name and identity will always be kept confidential 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 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. Once you have completed the documents you are welcome to discuss this in an informal manner afterwards.

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,
Peter Mongoatse Teffo

In-service teacher's Consent Form

Name of the researcher: Mr Mongoatse Peter Teffo

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called:

THE INFLUENCE OF EXPERIENCE ON TEACHER TOPIC SPECIFIC PCK (TSPCK) ON CHEMICAL EQUILIBRIUM

I, ______________________ give my consent for the following:

Permission to review/collect documents/artifacts	**Circle one**
I agree that my participation will remain anonymous	YES NO
I agree to complete the TSPCK and CK tools in Chemical equilibrium.	YES NO
I agree that the completed tools be used for this project.	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.
- all the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________ Date 26/08/2019

Appendix 3: **Chemical Equilibrium CK achievement test**

CHEMICAL EQUILIBRIUM ACHIEVEMENT TEST

CATERGORY A:

1. Consider the reaction which is at equilibrium

$$C_2H_5NH_2\,(aq) + H_2O\,(l) \rightleftarrows C_2H_5NH_3^+\,(aq) + OH^-\,(aq)$$

Look carefully at the equation and decide which of the following statements about the reaction at equilibrium is **CORRECT.**

A. The reverse rate of reaction is lower than the forward rate of reaction.
B. The forward rate of reaction is greater than the reverse rate of reaction
C. The forward and reverse rates are equal.
D. The concentration of reactants is higher than that of products.
E. The concentration of reactants is lower than that of products.
F. The concentration of reactants and products is the same.

i. A and D only
ii. C and F only
iii. B and E only
iv. C and E only
v. A and E only

Your answer is…. Provide a detailed explanation for the answer you have chosen.

2. For the reaction $2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$

which of the following is **FALSE** about the reaction when at equilibrium

A. the constant for the reaction is equal to concentrations of reactants divided by the concentrations of products.

B. the rate of change of concentrations of reactants and products is constant.

C. the concentration of NO equals the concentration of NOCl.

i. A and B only
ii. A and C only
iii. C only
iv. B only
v. A only

Your answer is…. Provide a detailed explanation for the answer you have chosen.

3. Look at the equilibrium reaction represented by the equation:

$$N_2O_4\ (g) \rightleftharpoons 2NO_2\ (g)$$

Which of the following statements concerning this reaction at equilibrium is **FALSE**?

A. The ratio of the concentration of N_2O_4 *(g)* to the concentration of NO_2 *(g)* is 1 to 2.
B. From the balanced equation, it is clear that 1 molecule of N_2O_4 *(g)* produces 2 molecules of NO_2 *(g)*.
C. The equilibrium constant K_C, is $K_C = \frac{[NO_2]^2}{[N_2O_4]} = \frac{2^2}{1} = 4$

(i). (A) only.
(ii). (A), (B) and (C).
(iii). (A) only.
(iv). (B) only
(v). (A) and (C) only
(vi). (C) only

.

An answer option indicating A and C as false was missing in the tool used in the study, thus this question

Your answer is…. Provide a detailed explanation for the answer you have chosen.

4. Consider H_2 and I_2 molecules that undergo a reaction to form hydrogen iodide by providing suitable conditions in a closed system and reached equilibrium.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

We can use representations such as a solid sphere● to represent a single hydrogen atom, and an empty spheres ○ to represent a single iodine atom, then the equation may be expressed as follows:

●● + ○○ ⇌ **2**●○

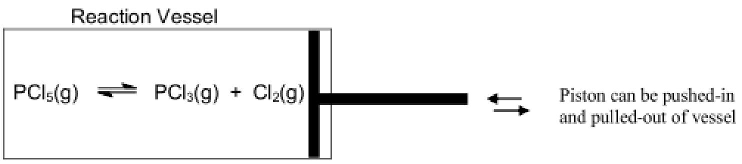
Use representations shown above; to draw

i. A representation of the system at the beginning of the reaction with 4 hydrogen molecules and 3 iodine molecules.
ii. At equilibrium
iii. 2hrs after reaching equilibrium

At the Beginning of the Reaction:	**At Equilibrium:**	**2 hrs after reaching Equilibrium:**
Drawing:	Drawing:	Drawing:
Explain your drawing	Explain your drawing	Explain your drawing

CATERGORY B:

5. The reaction $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ is at equilibrium in an empty reaction vessel fitted with a movable piston.



5(a). What will happen if some argon (an inert gas) is added to the equilibrium mixture at constant pressure and temperature?

A. More $PCl_3(g)$ and $Cl_2(g)$will be formed.
B. The total pressure will increase instantaneously, PCl_3 molecules will combine with Cl_2 thus more $PCl_5(g)$ will be formed.
C. There will be no effect because argon does not react with any of the substances in the equilibrium mixture.

Your answer is…. Provide a detailed explanation for the answer you have chosen.

5(b). What will happen if the piston is pushed into the equilibrium mixture, reducing the total volume of the vessel?

A. More $PCl_3(g)$ and $Cl_2(g)$ will be formed.
B. More $PCl_5(g)$ will be formed.
C. There will be no effect because no additional reactant or product was added.

Your answer is…. Provide a detailed explanation for the answer you have chosen.

6. The decomposition of ammonium chloride reaches equilibrium in a closed container at a given temperature

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$$

Write the equation for K_c for this reaction   Explain your equation

7. In a vessel of volume 10 L, 10 mol NH_3, 2 mol N_2, and 1 mol H_2 are present at equilibrium. Calculate the value of the equilibrium constant, K_c for the equilibrium

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g).$$

8. In a solution of acetic acid in water the following equilibrium is established:

$$CH_3CO_2H(aq) + H_2O(l) \rightleftharpoons CH_3CO_2^-(aq) + H_3O^+(aq)$$

To begin with we have 100 ml of a 1.0 M solution of acetic acid, and then enough water is added to obtain 1 L of a new solution:

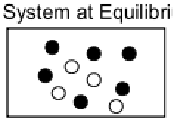
(8a) Predict the possible effect of adding water to the equilibrium position.

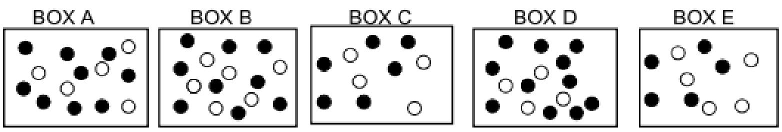
(8b) Explain the reasons behind your prediction in (8a) above.

CATERGORY C:

9. The exothermic reaction ○ (g) ⇌ ● (g) was allowed to come to equilibrium, as represented in the box below:

System at Equilibrium





A. Some ● was added to the system at equilibrium. Which box (A–E) best represents the new position of equilibrium? Explain your answer.

Your answer is….

Provide a detailed explanation for the answer you have chosen.

B. The temperature of the system at equilibrium was increased. Which box (A–E) best represents the new position of equilibrium? Explain your answer.

Your answer is…. Provide a detailed explanation for the answer you have chosen.

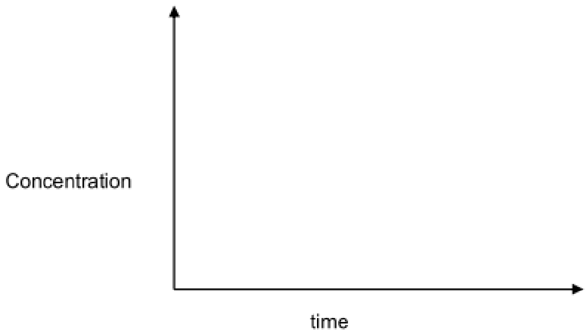
C. The pressure of the system at equilibrium was increased. Which box (A–E) best represents the new position of equilibrium? Explain your answer.

Your answer is…. Provide a detailed explanation for the answer you have chosen.

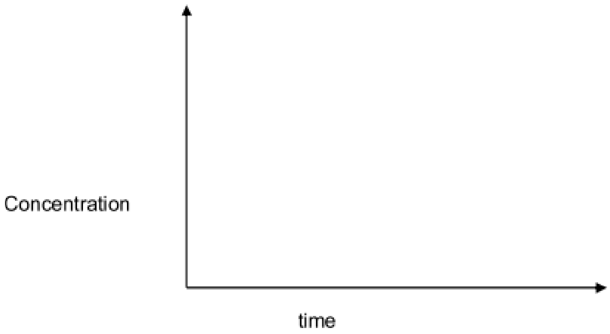
10. For the reaction $N_2O_4(g)$ + Heat $\rightleftharpoons$ $2NO_2(g)$ at equilibrium at a given constant pressure:

Draw concentration versus time graphs showing:

10(a). As the reaction is reaching equilibrium.



10(b). The effect of adding more N_2O_4 gas into the container



Appendix 4: Chemical Equilibrium TSPCK test

Code:

CATEGORY A: LEARNERS' PRIOR KNOWLEDGE

1. What comment would you write on a learner's script who writes:

A reaction reaches equilibrium when the concentrations of the products and reactants are equal.

Response A: No; when a reaction reaches equilibrium it does not mean the concentrations of the reactants and products are equal. The concentration of reactants and those of products are not equal at equilibrium. Sometimes the concentration of reactants is more than that of products and vice-versa. It depends on the type of reaction.

Response B: No; when a reaction reaches equilibrium the concentration of the products and the reactants are not equal. Equilibrium is reached when both reactions proceed at the same rate.

Response C: No; the concentration of reactants and products at equilibrium are not necessarily equal. Each reagent may have its own concentration which is different to the other. What ensures a reaction to be at equilibrium is the rate at which the forward and the reverse reaction occur. For equilibrium to occur this rate must be equal for both reactions.

Response D: None of the above

Choose your response, and use the space below to expand on your choice.

My choice is Response.....

2. In a classroom setting, which of the following responses will you choose to answer a learner who seems to be in doubt and asks you:

"Do both the forward and the backward reaction actually take place if a closed system is at equilibrium?"

Response A: Yes; the rate at which the forward reaction occurs is the same as the rate at which the backward reaction occurs.

Response B: Yes; for a reaction to be considered as at equilibrium, the rate of the forward reaction is the same as the rate of the reverse reaction. As products are formed, they decompose or react with each other and form reactants. In this way the reaction is kept at equilibrium.

Response C: Yes; a reaction that is at equilibrium has a forward and a reverse reaction. The forward reaction produces products and the reverse reaction produces reactants. Sometimes the concentration of products is higher than reactants, sometimes vice versa.

Response D: None of the above.

Choose your response, and use the space below to expand on your choice.

My choice is Response .....

CATEGORY B: CURRICULUM AWARENESS

3. Questions 3.1 -3.4 relate to planning and sequencing of concepts.

3.1 What do you consider to be the **three main ideas** (main concepts) to be taught about equilibrium at Grade 12? Choose from the list provided.

Dynamic equilibrium	Equilibrium constant
Chemical reactions	Rate of reaction
Lê Chatelier's principle	Equilibrium shift
Factors that affect equilibrium	Calculation of equilibrium concentrations
Open and closed systems	Homogeneous and Heterogeneous equilibrium
Physical equilibrium	Forward reaction and reverse reaction
Extent of reaction	Other

1.
2.
3.

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

3.3 What topics must have been covered in chemistry before you can teach chemical equilibrium?

List of Topics to be taught before Chemical Equilibrium	**Place them in a sequence** (the one to be taught first , place it as No. 1)	**Provide reasons for the proposed sequence**
	1.	
	2.	
	3.	
	4.	

3.4 Why is it important for learners to learn about equilibrium? Identify reasons related to:

i. Conceptual Progression
ii. Application

iii. Motivation or Interest

CATEGORY C: WHAT MAKES THE TOPIC DIFFICULT TO UNDERSTAND?

4. Tick (✓) from the list below, concepts of chemical equilibrium you consider difficult to teach? You may also add your own. Explain why you consider the chosen topics difficult to teach.

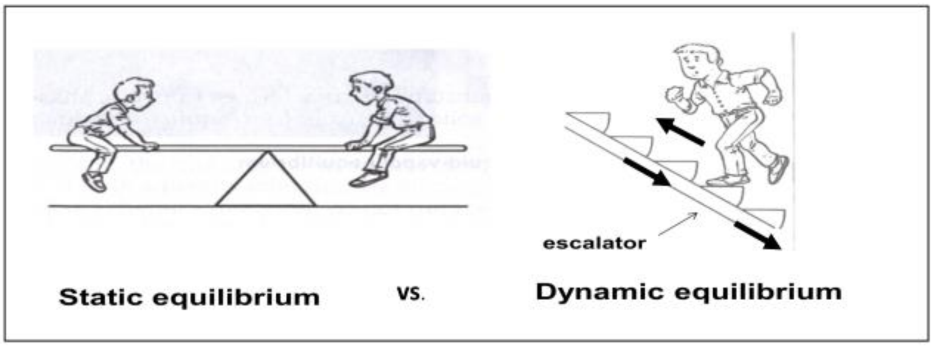
Concept	✓	Why considered difficult?
Closed and open system		
The calculation of concentration using the (RICE) **R**atio/ **I**nitial/**C**oncentration/**E**quilibrium Table		
Physical equilibrium vs. chemical equilibrium		
Calculations of concentrations vs. calculations of moles		

Concept	✓	Why considered difficult?
Working with the equilibrium constant in calculations, just a number with no units		
Using mathematical ratios in a chemical concept		
Dynamic equilibrium – in chemical systems		

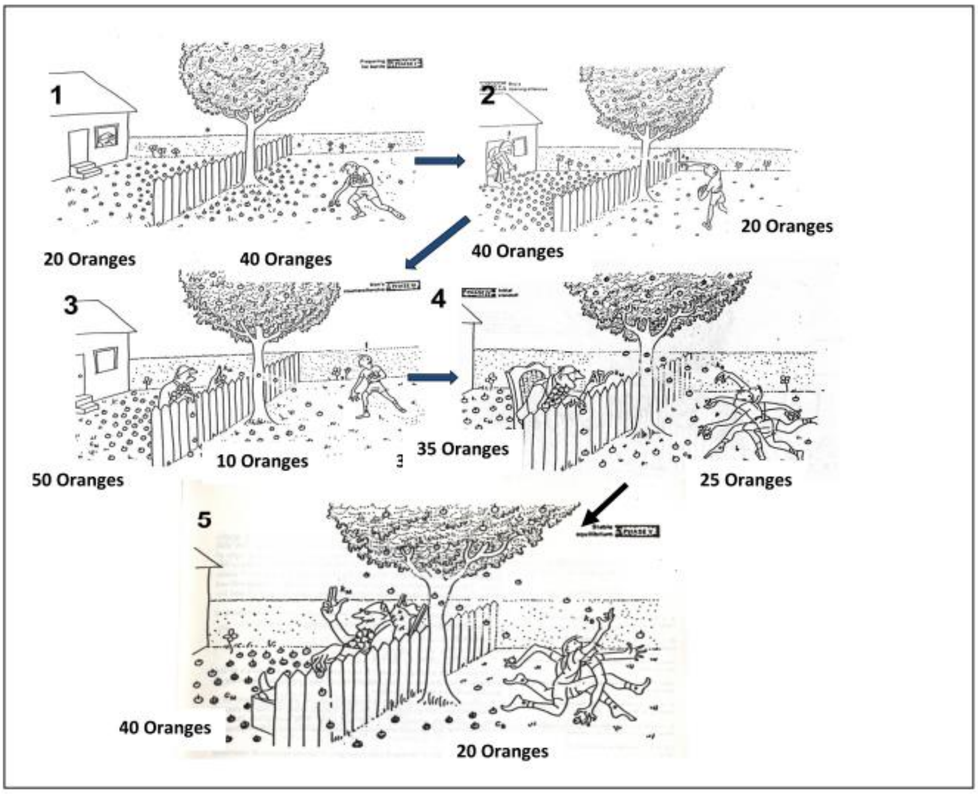
CATEGORY D: REPRESENTATIONS/ANALOGIES/MODELS

Dynamic and Static equilibrium

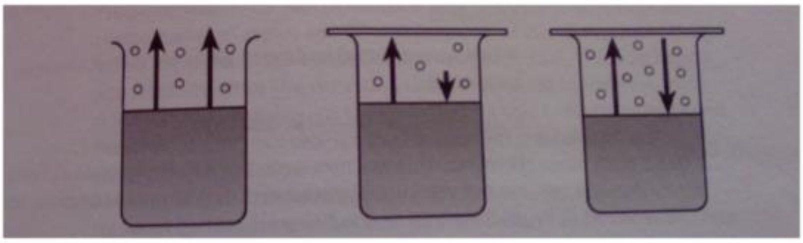
5. Below are possible representations/analogies/models for teaching the concept of static versus dynamic equilibrium.



Representation 2



Representation 3



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

Representation No.	What I Like	What I do not like
1		
2		
3		

5.2 Which representation do you like most?

5.3 How would you use the representation that you like most?

<u>CATEGORY E: TEACHING STRATEGIES</u>

<u>Le Châtelier's' Principle</u>

6. Following below is a student's written response in a class test designed to assess prior knowledge of students about Le Châtelier's' Principle.

Question:

What is the effect of adding more water to reaction given below at equilibrium?

$$CH_3CO_2H(aq) + H_2O\ (l) \rightleftharpoons CH_3CO_2^-\ (aq) + H_3O^+(aq)$$

A student responded:

'More $CH_3CO_2^-$ (aq) and H_3O^+ (aq) will be formed, to counter act the effect of adding more water to the reactants. This will happen until a new equilibrium is reached'.

6.1 Following the student's response, how will you teach a lesson on predicting the effect of factors disturbing the equilibrium?

Appendix 5: 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 6: Interview questions for teachers

Interview questions for teachers

Professional Development Activities within Last 8 Years

1. Do you currently teach grade 12 Physical Science?
2. How many times have you taught it for the past 8 years?
3. have you ever marked grade 12 National Senior Certificate paper 2 in the past eight years? How many times?
4. Have you ever observed other teachers teaching chemical equilibrium? How many times?
5. Have you attended any workshop on science teaching about Chemical Equilibrium? How many times
6. Have you ever met with local teachers to discuss science teaching issues? How often do you discuss about chemical Equilibrium in your meetings?
7. Since you completed BE.d have you ever registered with or completed any college or University course in science? Name the qualification.
8. Have you ever attended any science teaching conference? Were any of the presentations/workshops on Chemical Equilibrium or other related topics? How many of such conferences have you attended?
9. Have you ever served as a mentor and/ or peer coach in science teaching as part of a formal arrangement that is recognised and supported by the school or district about chemical equilibrium? Explain your responsibility in such a role
10. Have you ever collaborated on science teaching issues with a group of teachers at a distance using telecommunication? Did such a collaboration involve chemical equilibrium concepts? Please elaborate
11. Have you ever read anyliterature about best ways of teaching or effective teaching? If yes, how often? What have you learned from such literature?
12. Are there any other ways you normally use to improve your teaching knowledge and skills?

I designed interview questions, using existing items, such as those available from Horizon Research, Inc. (2003) and creating new questions, they will be used to collect data about science teachers' experiences. http://www.teach-math-or-science.org/docs/ PD_inventory_Summary.pdf.