Exploring the relationship between the pre-service teachers' nature of TSPCK acquired in planning and that enacted in classroom practice.

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Mpumelelo Faith Zondi

Abstract

This study explored the relationship between the physical science pre-service teachers' nature of topic specific pedagogical content knowledge (tsPCK) acquired in planning and that enacted in the classroom teaching of stoichiometry. The research study was based on the construct of tsPCK developed by Mavhunga (2012) as it focused on the knowledge required for transforming the content knowledge of a specific science topic. The study was performed on three groups of fourth year pre-service teachers doing a physical science methodology course at a university in South Africa. There were 12 participants in total. Collected data included the lesson plans, video-recordings of microteaching, and reflection reports; all done by the participant pre-service teachers in the stoichiometry. The research used an in-depth qualitative method to analyse the results by looking for possible moments of integration of tsPCK components represented by tsPCK maps. The validated tsPCK rubric was used to quantify the observed tsPCK episodes and describe the quality of tsPCK. An analysis of the collected data revealed that even though there was a relationship in terms of components in the lesson plans and enacted lesson, the enacted lessons had a better quality than the lesson plans. It was also observed that most of the enacted lessons were interwoven and had more knowledge components of tsPCK than the lesson plans. The implications of the study were discussed.

Key words

tsPCK – Topic Specific Pedagogical Content Knowledge cPCK – Collective Pedagogical Content Knowledge pPCK – Personal Pedagogical Content Knowledge ePCK – Enacted Pedagogical Content Knowledge

DoBE – Department of Basic Education

Dedication

To my Lord and personal saviour, Jesus Christ: Thank you for being my strength and pillar when I was weak. ***Soli Deo gloria.***

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Lastly, to all the teachers who willingly agreed to participate in my research project and took their valuable time to help me. Thank you for allowing me to use your videos, lesson plans and your reflection reports. I appreciate the time you set aside in your busy schedules.

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CHAPTER 1

1 INTRODUCTION TO THE STUDY

1.1 Introduction

Lesson planning is a vital element in teaching and it goes beyond mere production of lesson plans. This is a view supported by Shulman (1987) who adds that planning for a lesson evokes a process of pedagogical reasoning. The process begins with comprehension; whereby a teacher is expected to understand what they are teaching. When possible, to also understand the content of their lessons in numerous ways that require them to look at an idea from different perspectives while also thinking about what representations to use and how to use them. Shulman (1987) argued that, in doing so, the teacher is transforming the knowledge that they possess into forms that are pedagogically powerful. It is not adequate for a teacher to understand knowledge in one way. They need to understand it in many ways so as to offer alternative explanations, should students find one approach difficult (Bishop & Denley, 2007). Shulman (1987) adds that the transformation is a key element of Pedagogical Content Knowledge (PCK) as it facilitates learner understanding. Thus, a teacher who is able to generate explanations of difficult and abstract concepts in ways that learners can understand, despite their diversity, is said to have a good quality of PCK.

This study explores PCK as the teachers' professional knowledge for teaching science topics. The science education community regards PCK as the professional knowledge for teaching science (Karal & Alev, 2016). There is a general agreement that learning to transform content knowledge is a central element of PCK that should be passed on to prospective teachers (Mavhunga, 2016). There is also an agreement that the value of teaching PCK to pre-service teachers lies in demonstrating and teaching PCK within a discipline's topics (Abell, 2007). Exploration of the possible practical ways for implementing PCK within specific topics in science education was introduced by Mavhunga and Rollnick (2013). The authors reconceptualised PCK in a specific topic as a valid theoretical construct termed Topic Specific Pedagogical content knowledge (TSPCK). TSPCK refers to the understanding and the competence to pedagogically transform concepts in a specific topic using the content specific components of the construct in multiples and interactively (Mavhunga and Rollnick, 2013).

TSPCK fits into the consensus model of PCK as the layer of PCK referred to as Topic Specific Pedagogical Knowledge (TSPK) in the consensus model (Gess-Newsome, 2015). The newly Refined Consensus Model of PCK refers to topic specific PCK as one of the layers of PCK that exists in the collective, personal, and enacted categories or broad spheres of PCK. This thesis refers to both the model and its layers in detail in Chapter 2. Nonetheless, it is important to note that this study is located within a broader research project that focuses on PCK in specific topics; that is, TSPCK in various topics.

Previous studies, within the broader research project, have explored the development and measured the extent of the improvement in the quality of TSPCK in various topics with pre-service teachers. In chemistry, it was shown that a particular intervention discussing the development of the competence to transform content knowledge explicitly using the content specific components of TSPCK in chemical equilibrium, resulted in a significant improvement in the quality of TSPCK in the topic (Mavhunga & Rollnick, 2013). In another study, using a similarly structured intervention with a physics topic – kinematics, it was reported that pre-service teachers were able to transfer the pedagogical competences learned into application in novel science topics in physical science (Mavhunga et al, 2016). Similar findings were observed with a study where an intervention was done with the topic of particulate nature of study and good transfer of the competence to transform content knowledge was observed in a new topic perceived to be more difficult to understand: chemical equilibrium. The finding about the transfer of pedagogical competencies that enables pre-service teachers to transform content knowledge is critical to the PCK literature because PCK is known to be topic specific (Van Driel, 1998); it cannot be transferred. However, the transfer of pedagogical competence that enabled transformation of content knowledge in a new topic meant that the pre-service teachers could continuously self-develop their TSPCK in new science topics. While these recent developments add value to understanding about the development of PCK in specific topics as TSPCK, all these studies were limited in a sense that they had a focus on developing TSPCK in a planning context without extending the exploration into the classroom context. Thus, at present, little is known and available in the literature about how TSPCK, acquired in a context of planning for teaching as shown by the above listed studies, is demonstrated out in a classroom context. In addition, little is also known at present about whether there is an empirical evidence pointing to the nature of the relationship between the quality of planned TSPCK vs. enacted TSPCK. This is the gap in the literature that this study is aiming to contribute towards. The study is nested in the specific topic of stoichiometry because the topic is perceived to be difficult to teach. For example, Bridges (2015) argues, based on a study on stoichiometry, that many students have problems learning stoichiometry due to teachers' lack of understanding of how to teach the topic. Solving stoichiometric problems requires more than mere calculations. It involves the stringing together of many steps using conceptually organized knowledge (Ayoade, 2012); something that has been shown to pose difficulty to many students.

1.2 Statement of the problem

While many scholars, including Shulman (1987), support the development of sound reasoning at a planning level in teaching as it influences how teachers teach, it is however widely accepted that, the ultimate test lies in what happens in classroom practice. The lack of an established understanding of how TSPCK acquired in a teacher training course, with a focus on learning to plan for teaching, would translate into TSPCK in practice is problematic. This means that teacher development programmes implementing TSPCK would be in the dark about the effectiveness and the usefulness of the examples they use in their programmes. Also, there is no clarity whether such courses display and pitch their activities at the appropriate complexity as naturally displayed in a classroom. The problem of not knowing how one's theoretical effort translates to real practice promotes the existing long-standing theory-practice gap in science education. Therefore, it is important that the actual complexity of the classroom is first understood and brought into influencing how teaching is done. So, this study explored whether there is a relationship between the quality of TSPCK in planning and practice. If the conclusion is that there is none, what could be done? It is anticipated that the value of this study would be a direct contribution towards informing the depth of the practical tasks used in the complex task of developing PCK with pre-service teachers. Furthermore, the findings may enhance teacher educators' thinking about what pre-service teachers need to learn and to what depth science teacher education programs need to offer it (Nilsson & Loughran, 2012).

1.3 Rationale

Mathematics and Science education have been regarded as significant learning areas in South Africa. This is a reality noted by Reddy (2006) who argued that these subjects are key knowledge and competence for the development of South Africa in a globalizing world. In addition, it has been indicated that the quality of mathematics and science education in South Africa is a cause for concern and this can be ascribed to many mathematics and science teachers' limited content knowledge, ineffective teaching approaches, and unprofessional attitudes (Kriek & Grayson, 2009). The majority of teachers at the tertiary level are not formally qualified to teach, and although they have appropriate content knowledge, they may lack the ability to transform their content knowledge into teachable forms (Davidowitz & Rollnick, 2011). This means that successful science teachers are teachers who can develop appropriate strategies and representations of science knowledge to accomplish fruitful teaching (Jang & Tsai, 2012). Science teachers' knowledge is important as Ball et al (2008) stated, ''Teachers cannot help children learn things they themselves do not understand'' (p. 5).

1.3.1 Why the focus on developing pre-service teachers' knowledge?

It is believed that students' performance in the classroom is the product of what the teacher taught. Feiman-Nemser (2001) agrees with this view and argues that what students learn is directly related to what and how teachers teach. Shulman (1987) points out that the thoughts that influence teachers' classroom instructions happens firstly in the transformation stage, an important planning stage which goes beyond the actual delivery of the lesson. Compared to in-service teachers, Driel, Verloop & Vos (1998) say that pre-service teachers seem to have little or no PCK as compared their in-service counterparts. Mavhunga et al. (2016) argued that PCK is widely taken to be a specific topic and cannot be transferable from one topic to another. However, it can be developed through experience and its early development is desirable in pre-service teachers while they are learning to teach. This means that developing pre-service teachers' knowledge in teaching is crucial and has the potential to improve their knowledge before they start teaching.

Feiman-Nemser (2001) argued that since teachers are responsible for helping students learn meaningful content, they must know and understand what they teach. This means that teachers must be trained on what to teach and how to transform the content they are teaching. Nilsson (2011) adds that PCK is a complex construct and capturing it in practice has proved extremely difficult. However, the same scholar notes that this could change if pre-service teachers were offered meaningful ways of defining, identifying, assessing, and explicitly developing PCK.

1.3.2 Why focus on stoichiometry as a topic?

Stoichiometry has played a key role in marking the difference between qualitative and quantitative chemistry (Padilla & Garritz, 2011). Understanding stoichiometry is an important part of learning chemistry, but student understanding of this concept is low, with many students demonstrating surface learning only (Bridges, 2015). Teachers also struggle with teaching stoichiometry; which impacts the learning and understanding of stoichiometry by learners (FeimanNemser, 2001). This is because when the teacher is struggling with a concept or topic, it is difficult for learners to understand the topic.

Table 1.1: Percentage performance in National Senior Certificate Physical Sciences Paper 2 (DoBE, 2015, 2014, 2013)

Annual Performance in Percentages	2013	2014	2015
Organic Nomenclature	60.5	65	62
Organic Compounds &Stoichiometry	44.5	47	36
Reaction Rates &Stoichiometry	33.2	36	35
Acid and Bases &Stoichiometry	44.4	48	37
Fertilisers	42.5	58	50

From the Table 1.1, it is clear that performance in all topics or questions that had stoichiometry aspects seem to have visibly deteriorated from around 40% in 2014 down to mid-30% in 2015.

1.4 Research questions

This study aimed to explore the relationship between the pre-service teachers' quality of TSPCK acquired in planning and that enacted in classroom practice. The following research questions guided the investigation

1. What is the quality of TSPCK evident in the pre-service teachers' planning for teaching stoichiometry?

2. What is the quality of TSPCK evident in a teaching setting of stoichiometry by pre-service teachers?

3. What is the relationship, if any, between the quality of TSPCK in pre-service teachers' planning and classroom teaching of stoichiometry?

1.5 Report outline

Chapter 1 of this report introduces the research topic, the problem statement, and also discusses the rationale with the research questions. The literature review is presented in Chapter 2; which covered the aspect of TSPCK in both planning and actual teaching revolving around the theoretical framework. In chapter 3, there are discussions on the research design and methods of collecting data employed in this study. Chapter 4 covers the analysis of the pre-service teachers' enacted TSPCK captured in lesson planning. This was followed by Chapter 5 where I presented the analysis of the pre-service teachers' classroom teaching and described their enacted TSPCK. In Chapter 6, the presented discussions cover pre-service teachers' enacted TSPCK in planning as it related to their enacted TSPCK in the actual teaching. Chapter 7 covers the answers to the research questions guiding this study, recommendations, limitations of the study, and reflections.

CHAPTER 2

2 Literature Review

2.1 Introduction

This research is based on Mavhunga and Rollnick's (2013) construct of Topic Specific Pedagogical Content Knowledge (TSPCK). This chapter will review the teacher professional knowledge for teaching science, PCK taught to pre-service teachers, teaching and learning difficulties in stoichiometry and microteaching, and its use in teacher education. The model of teacher professional knowledge will be used to expand on Mavhunga and Rollnick's (2013) Topic Specific PCK model. The relevance of using TSPCK model in teaching stoichiometry will also be discussed.

2.2 Theory practice gap

The objective of the teacher education programme is to equip student teachers with a set of competencies, which might be personal and context specific (Banks et al. 2001). Pre-service teachers learn from two different locations. The first location is at the university which is commonly known to represent the place of theory and the second location is the classroom at a school which is representing the place of practice (White & Forgasz, 2016). When teachers have learnt different theories of pre-service teaching they are supposed to go to schools to practice or apply what they learned on campus (Zeichner, 2010). However, Cheng, Cheng, and Tang (2010) argue that as teachers attempt to apply what they have learnt, there is a gap between the theory and practice of teaching. That gap, which is perceived as soon as student teachers enter the real classroom setting, is an issue of concern in teacher education (Hascher et al. 2004).

Cheng, Cheng, and Tang (2010) advance some of the reasons for this gap: the pre-service teachers' misinterpretation of the theory, its faulty implementation, or possibly the inadequacy of the theory itself. (The literature indicates the necessity of understanding the link between theory and practice. For example, Campbell and Hu (2010) indicate that most problems and debates that informed reforms in the pre-service teachers' experiences of teaching emanated from the observed gap between theory and practice. Cheng, Cheng, and Tang (2010) argued that many newly learnt teaching theories or conceptions developed during teacher education programmes are 'diluted' by the preliminary conflict during their teaching practice .

Other studies show that student teachers feel there is a lack of 'connection' between the teacher education programme and the school-based teaching experiences (Hobson, Malderez, Tracey, Giannakaki, Pell, & Tomlinson, 2008). The disconnect between what students are taught in campus courses and their opportunities for learning to enact these practices in their school placements is often very great (Cheng, Cheng, & Tang, 2010)

The main concern portraying the gap is how either theory or practice should inform the other to better shape pre-service teachers' understanding and learning (Loughran & Hamilton, 2016). Efforts made in exploring teachers' development in the theory and practice contexts target improving teacher quality, quality of instruction, and ultimately learning outcomes. While describing teacher quality, Blomeke, Olsen and Suhl (2016) point out teachers' content knowledge (CK), pedagogical content knowledge (PCK), and general pedagogical knowledge (PK) as characteristics that influence learners' outcomes. So, there is a need to find out why there is a gap between theory and practice and how to close the gap. This study aims to find out if there is any gap or congruency between planning and actual teaching using the TSPCK construct

2.3 PCK taught to pre-service teachers

The place of Pedagogical Content Knowledge (PCK) in the science education literature has attracted considerable attention ever since its introduction by Shulman (1986) (P Nilsson, 2008). In science education, the construct of teachers' PCK has been productive and valuable since its conception by Shulman (1986). Many pre-service teachers entering teacher education courses are naïve about the cognitive demands (Pernilla Nilsson & Loughran, 2012) of teaching and how they will influence their work (Hume & Berry, 2011). They actually lack a deep conceptual understanding of science, such that their ideas about particular science topics are uneven and disorganized (Loughran, Berry, Mulhall, & Woolnough, 2006).

Pre-service teachers often have misconceptions and fragmented knowledge that limits their ability to create challenging learning situations; making it necessary for their PCK to be developed (Tondeur et al., 2012). This implies that if pre-service teachers are to be successful in creating classroom environments in which subject matter and pedagogy are integrated in a way that promotes learning, they must experience such learning environments themselves (Pernilla, Nilsson & Loughran, 2012). The value of PCK in teacher preparation programmes is said to lie in its usefulness in understanding teachers' knowledge (Abell, 2007). Mavhunga and Rollnick (2013) add that the implication for teacher preparation programmes is, therefore, that pre-service teachers need not only to learn how to teach but how to teach specific concepts.

Given the importance of teacher knowledge for student development, teacher education can be viewed as a key target educational improvement (Tondeur et al., 2012). This superficial grasp of subject matter by novice teachers tends to result in pedagogy that is intent on delivering facts. It is, however, incompetent when it comes to accessing key ideas that their students need for science understanding in the immediacy of the classroom teaching and learning environment (Magnusson, Krajcik, & Borko, 1999). This is a reality which leads scholars like Loughran et al. (2006) to advice that a pre-service science teacher educator should possess PCK to help them investigate and come to understand the complexity of learning to teach science.

2.4 Teaching and Learning difficulties in Stoichiometry

> Chemistry is the science of matter and of its transformations, and life in its highest expression, It provides structures endowed with properties and develops processes for the synthesis of structures and it plays a primordial role in our understanding of material phenomena, in our capability to act upon them, to modify them, to control them and to invent new expressions of them (Lehn & Sanders, 1995, p. 1).

Chemistry learning requires much intelligent thought because the content contains many abstract concepts such as dissolution, particulate nature of matter, and stoichiometry which are essential to learning chemistry. Unless these essentials are understood, topics such as rate of reaction, acids and bases, electrochemistry, chemical equilibrium, and solution chemistry become difficult to comprehend (Sirhan, 2007). Upahi and Olorundare (2012) agree with this view and add that the concepts and principles in chemistry range from concrete to abstract.

Stoichiometry has played a key role in the evolution of chemistry as a science; marking the difference between qualitative and quantitative chemistry (Kira Padilla & Van Driel, 2011). It is the quantitative aspect of chemical formulas and reactions (Upahi & Olorundare, 2012). It is a tricky topic for students because if they get one part wrong, usually the following part will be wrong too. For instance, Upahi and Olorundare (2012) argued that in order to actually calculate the quantities of substances consumed or produced in a chemical reaction, it is necessary to first write a correct and balanced chemical equation for the reaction(s). Bridges (2015) also argued that understanding stoichiometry is an important part of learning chemistry. However, the same author notes that student understanding of this concept is low, with many students demonstrating surface learning only. For solving stoichiometry problems, in addition to demonstrating an understanding of chemical reactions, the student must be able to apply the principles involved in ratio and proportion calculations (Upahi & Olorundare, 2012).

Stoichiometry is considered a difficult topic for students as understanding depends on various other topics, such as the particulate nature of matter, the concept of mole, Avogadro's number, conservation of matter, balancing chemical equations, and the laws of definite and multiple proportions (Padilla & Garritz, 2011). So, in order for teachers to help students to learn about stoichiometry, they must pay attention to the development of traditional subject matter knowledge (Bridges, 2015). This also implies that teachers should use different and most interesting strategies with different kinds of representations to improve learning of Stoichiometry. Padilla, and Garritz (2011) say that these representations can be historical, analogical, visual, analogue maps, lab experiments or demonstrations, molecular models, and material models. Many other proposals, to teach Stoichiometry, suggest the importance of contextualizing exercises and lab work to make it interesting and motivational to students. The role of teachers is important to promoting student understanding of stoichiometry; they must know how to present the material in creative and resourceful ways to ensure that their students are developing an understanding of the subject matter (Bridges, 2015).

Sirhan (2007) states that because chemistry topics are generally related to, or based on the structure of matter, chemistry proves to be a difficult subject for many students. Because of its abstractness, stoichiometry is one of the difficult topics in Chemistry, (Upahi & Olorundare, 2012).Bridges (2015) argues that in order to teach stoichiometry in a meaningful manner, teachers must adapt their instructional strategies and modes of delivery so that they reflect students' learning styles. The same author also advices that teachers must pay attention to the development of traditional subject matter knowledge, stoichiometry knowledge, and pedagogy, as well as the interaction among these fields.

2.5 Microteaching and its use in teacher education

The major goal of a successful teacher-training program is to expose prospective teachers to effective teaching strategies and experiences (Yu et al., 2011). Microteaching is a technique that is used in teacher education where a teacher candidate teaches a small portion of a lesson to a small group of his or her classmates and teaching competencies are carried out under strict supervision (Kilic, 2010). It provides teachers with an opportunity to increase their teaching skills by improving various simple tasks in their teaching (Remesh, 2013). These simple tasks may include practice of instructional skills or techniques of teaching, the mastery of specific curriculum materials, or the demonstration of a particular teaching methodology (O'Connor, 2010). Microteaching helps to promote real-time teaching experiences, the central skills of microteaching such as presentation and reinforcement skills assist the novice teachers to learn the art of teaching at ease and to the maximum extent (Remesh, 2013). Its setting can provide both beginning and experienced teachers with a safe practice environment for the development of competencies in the techniques and skills of the profession (O'Connor, 2010). It is perceived that teachers practice their skills and knowledge about teaching in a better way in micro-teaching practices (Kuran, 2009).

Microteaching has its own limitations. For instance, O'Connor (2010) argues that in microteaching the complexities of the normal teaching encounter are reduced; possibly because it is not the actual teaching in a real classroom. Microteaching is usually a short lesson of five to twenty minutes. Mergler and Tangen (2010) say that some criticisms of microteaching are concerned with the artificial nature of the experience and student teachers' reduced enthusiasm. Gess-Newsome (1994) observed that limited time for preparation and wastefulness of microteaching may create obstacles in student teachers' teaching processes and lead them to develop reluctant attitudes in teaching experiences. Some other problems such as the cost and maintenance of equipment, budgetary constraints for student teachers, the limited amount of time for preparing materials, and the level of difficulty of material production combined to cause student teachers' lack of enthusiasm in microteaching (Mergler & Tangen, 2010)

Microteaching, however, focuses on sharpening and developing specific teaching skills and eliminating errors. It enables understanding of behaviours important in classroom teaching, increases the confidence of the student teacher, provides expert supervision and a constructive feedback, and above all it provides repeated practice without adverse consequences to the teacher or their students. The microteaching method contributes a lot to pre-service teachers in terms of PCK development. It includes some practices and theories about how a subject could be better taught through different strategies, methods, and techniques (Kartal, Kaya, Öztürk, & Ekici, 2012). Microteaching is a classroom practice considered in this research design. Hence, the importance of discussing its value here.

2.6 Theoretical framework

After the work of Shulman (1986); Bishop and Denley (2007); Nilsson (2008) and many other researchers, it became apparent that there were too many conflicting ideas on PCK. Therefore to reach a level of consensus, a group of researchers met in 2012 and created an agreed model; referred to Teacher Professional Knowledge (Consensus PCK Model) (Gess-Newsome, 2015, p. 31). This model is novel in that PCK is defined as both a knowledge base used in planning for and the delivery of topic-specific instruction in a very specific classroom context, and as a skill when involved in the act of teaching (Gess-Newsome, 2015). The consensus PCK model has been further refined to reflect the multidimensional nature of PCK (Carlson & Daehler, 2017). The new Refined Consensus Model (RCM) of PCK introduces three major realms of PCK: collective PCK (cPCK); personal PCK (pPCK); and enacted PCK (ePCK), as shown in Figure 2.1 below.

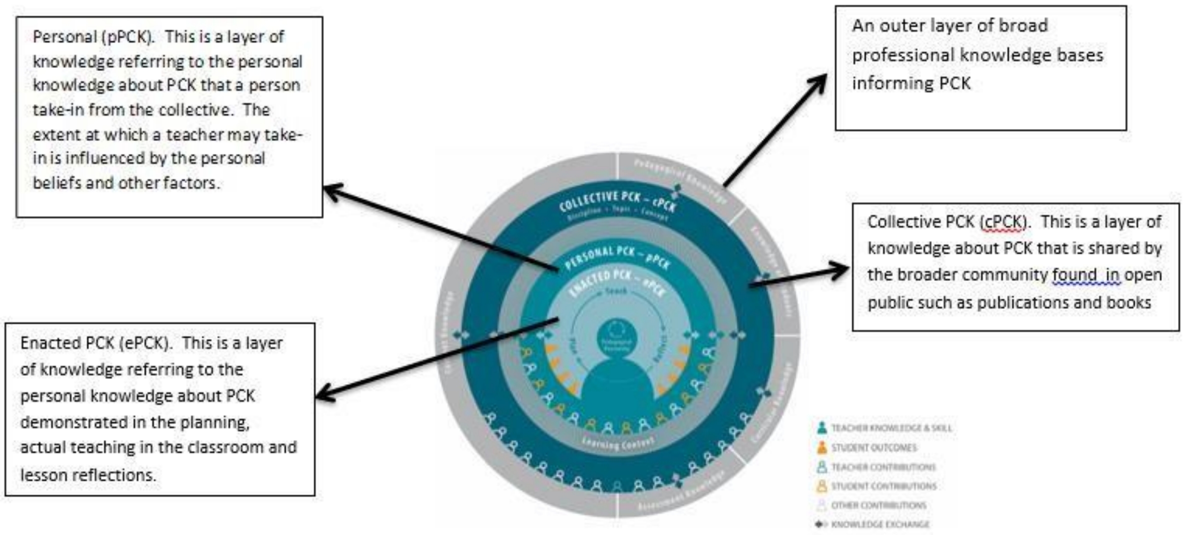


Figure 2.1: Refined Consensus Model (RCM) of PCK (Carlson & Daehler, 2017)

The model describes the complex layers of knowledge and experiences that shape and inform teachers' practice throughout their professional journey and, in turn, mediates student outcomes. A key feature of this model is the identification of three distinct realms of PCK: collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK).

The model significantly indicates the importance of developing PCK in a specific topic. In the first stage (first outer layer in Figure 2.1) there is Collective Pedagogical Content Knowledge (cPCK). This is a mixture of numerous educators' contributions which include the teacher's own contributions from the combined professional knowledge bases and varied teaching experiences within a given subject matter as understood and documented by many people (Carlson & Daehler, 2017). It is collective because it is published information that is known about PCK that is shared by the broader community of science education. This means that cPCK is a broad range of PCK. It can be seen from the outer circle that it includes pedagogical knowledge, knowledge of students, curriculum knowledge, and assessment knowledge. Collective PCK includes the knowledge that more than one person possesses: knowledge that is publicly known and held collectively (Carlson & Daehler, 2017). This would be knowledge from Shulman (1986) about PCK, Geddis and Wood

(1997) on components for transformation of content knowledge, Mavhunga and Rollnick (2013) on Topic specific Pedagogical Content knowledge (TSPCK) and many more.

In the second stage of the model, there is the Personal PCK (pPCK). This is the teacher's personal pedagogical content knowledge that is collective and dynamic. Here, the pedagogical content knowledge and skills of an individual teacher reflect on their own teaching and learning experiences together with the contribution of others such as educational researchers, teaching colleagues, scientists, social media, coursework, professional learning experiences, and contributions from students the teacher has ever taught (Carlson & Daehler, 2017). Personal PCK is how the teacher demonstrates their understanding of collective PCK which is shown in the out circle. A teacher's pPCK is a reservoir of skills and knowledge that the teacher can draw upon during the practice of teaching (Carlson & Daehler, 2017). Therefore, the teacher has learnt this in a coursework and that makes collective PCK published public knowledge. The teachers then take this collective PCK in and do the thinking about the cPCK, so that they have a special way in which they show their PCK. This is the unique way which the teacher demonstrates cPCK because now it is personal. Hence, it has a local consideration and they take it in context. This conception of "enacted PCK" reflects key ideas about the description of "personal PCK" as the knowledge of, reasoning behind, and planning for teaching a certain topic in a specific way for a particular purpose to a distinct group of students for enhanced student outcomes (Carlson & Daehler, 2017). This is shown in the ePCK circle whereby there is planning, teaching, and reflection. Enactment is a part of pPCK. The way one would act it out is personal, and the teacher would then enact it out. Its personal character is depicted in how the teacher would then act it out during teaching. Planning falls under pPCK, because the teacher is the one who plans the lesson and enacts it.

In the third stage of the model (inside circle in Figure 2.1) there is enacted PCK (ePCK). This is the knowledge that an individual teacher, in a specific setting, with a specific student or group of students, with a goal for those students to learn a specific concept, collection of concepts, or a specific aspect of the discipline, possesses (Carlson & Daehler, 2017). A significant feature of ePCK is the way in which the teachers' actions draw on their knowledge in order to meet the distinctive needs of learners in a classroom during a given teaching period (Carlson & Daehler, 2017). Hence, it can be concluded that enacted PCK is what the teacher shows in action.

The Refined Consensus Model (RCM) of PCK, introduced in (Carlson & Daehler, 2017), brings back to light the multidimensional nature of PCK. It is to be noted that the multidimensional nature of PCK emerges in the literature in different ways. Earlier studies have reported on the tacit nature of PCK and recommended for the observation of its manifestation in both a planning and enacted classroom conditions which are distinct contexts from each other (Park & Chen; Mehmet). A different set of studies reported on the differentiated grain-size of PCK, evident when the teaching of a particular discipline and a specific topic is considered (Nezlova, 2011; Veal, 2003). Some of these studies looked at PCK emerging from a perspective of a group of teachers (Loughran et al., 2006) or individual teachers (Aydin, 2014), how they impacted on learner understanding; the ultimate goal of PCK. It could be reasonably argued that the above listed studies presented multiple and different faces or perspectives of the same theoretical construct which has over the years posed a challenge to refer to either without ambiguity. The RCM model of PCK draws on all these perspectives of dimensions into a coherent interlinked pictorial representation. The representation illustrates the possible developmental path of how an individual teacher draws and develops a collection of professional knowledge from the collective understanding about PCK called cPCK. Thus, the model refers to cPCK, pPCK and ePCK as representing three distinct but interrelated realms of PCK through which a teacher may develop their professional knowledge. The development of PCK through the three realms could be experienced at differentiated depths: discipline; topic specific and concept specific levels. The discipline, topic specific or concept specific levels reflect the grain-size at which PCK could be considered at a particular time. The illustration in Figure 2.2 presents a simplified version of the RCM of PCK; illustrating simply the three realms of PCK and the grain-size levels within each realm. Thus, making it more imperative to distinguish the grain-size of PCK referred to at any point in time.

The development of PCK through the three realms could be experienced at differentiated depths: discipline specific, topic specific, and concept specific levels. These levels reflect the grain-size at which PCK could be considered at a particular time.

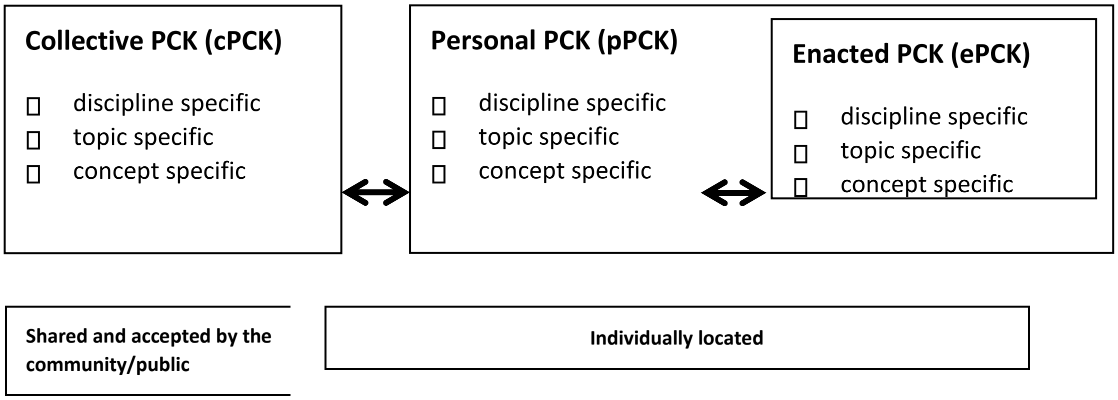


Figure 2.2: A simplified illustration displaying the multidimensional nature of PCK reflected in the RCM of PCK

It is important to note that Figure 2.2 is not a full representation of the RCM model. It only serves to help clarify how the model acknowledges and pulls together the multidimensional nature of PCK. This section explains the positioning of TSPCK, mentioned in the introduction and literature review, within the new RCM of PCK. TSPCK is now positioned as one of the grain-size of PCK, speaking to PCK in a topic within each of the three realms of PCK as shown in Figure 2.2. TSPCK has now been abbreviated as tsPCK hence forward in this study in alignment with the terminology in the RCM of PCK (Carlson & Daehler, 2017). In this study tsPCK is used as a theoretical framework to explore the congruency between planning and the actual delivery in a classroom. In terms of the RCM of PCK, this study is located in the enacted PCK realm. It is to be noted that the realm of enacted PCK (ePCK) encompasses planning, the actual teaching and reflections that a teacher does on their teaching practice. This study explores only the planning and the actual lesson delivery.

2.6.1 Explaining topic specific PCK (tsPCK) in detail

As mentioned earlier, topic specific PCK (tsPCK) is defined as the knowledge needed to transform concepts in a specific topic into forms that learners can understand with ease (Mavhunga & Rollnick, 2013). The discussion above has shown how tsPCK fits into the RCM of PCK. This unpacks the composition of tsPCK as a construct; to clarify its features which are key in the analysis of the data in this study.

Mavhunga and Rollnick (2013) drew their argument for tsPCK based on the process of transformation of content knowledge previously presented by Geddis and Wood (1997). Geddis and Wood (1997) attested that transformation of content knowledge emerges from the considerations of several different types of knowledge which are content specific. The resulting effect of such a consideration is that difficult concepts in a topic are transformed into versions that could be understood by learners. The different kinds of knowledge that enable such transformation were listed as learner prior knowledge, curricular saliency, what is difficult to understand, representations, and conceptual teaching strategies. Mavhunga and Rollnick (2013) developed this idea further; proving it to be a construct and suggested a model as shown in Figure 2.4 below.

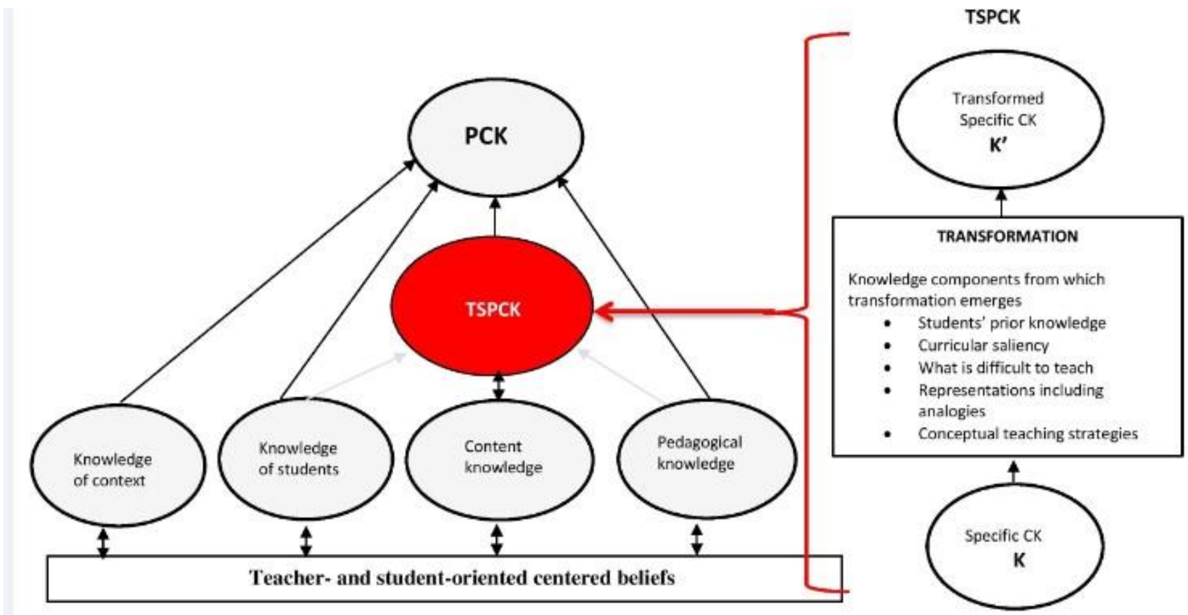


Figure 2.4: Mavhunga's (2012) topic specific PCK model (tsPCK)

The model proposed by Mavhunga and Rollnick (2013) considers five important content-specific knowledge components that collectively bring about the transformation of CK of a specific topic. The consensus model validates the components of tsPCK; initially identified by Geddis and Wood (1997).

The emphasis of the above model is that transformation of content knowledge is effectively done as a teacher reasons soundly through five essential components: learners' prior knowledge including misconceptions; curricular saliency; what makes the topic easy or difficult to understand; representations including powerful examples and analogies; and conceptual teaching strategies (Mavhunga, 2012, p. 20). According to Mavhunga and Rollnick (2013), the interest of the tsPCK model lies in developing teacher knowledge that may influence teaching practices within topics. This means that this model can be used to develop teachers' teaching practices in the classroom. The result of teachers knowing and reasoning their knowledge of a given topic through the five knowledge components is the transformation of their understanding into arrangements suitable for understanding by learners (Mavhunga & Rollnick, 2013).

The model, on Figure 2.4, shows a relationship between the teachers' quality of tsPCK acquired in planning (regarded as tsPCK in this study) and that which is enacted in classroom practice. This relationship, considering actual microteaching as the main platform, is the main target to explore in this study. tsPCK will be the main theory in exploring the relationship between pre-service teachers' quality of tsPCK acquired in planning and that enacted in classroom practice. This model explains the grain-size or the layer of PCK which talks to specific topics within each sphere in the RCM – the grain-size is referred to as tsPCK.

2.7 Quality of tsPCK defined

Many science education researchers attest, after Shulman (1987) that the importance of transformation of content knowledge as the key benefit from PCK, extended to TSPCK. The quality of PCK within a topic refers to both the conceptual understanding of the five content-specific components as well as their interaction (Mavhunga & Rollnick, 2013). Mavhunga and Rollnick (2013) argue that it is commonly accepted that Pedagogical Content Knowledge (PCK) has a topic-specific nature. This means that when teaching, PCK is needed. However, for every PCK that is applied there should be a specific topic. For example, this research will focus on stoichiometry as the specific topic and the extent to which the components of tSPCK interact, will be used as a measure of quality.

To explain the integration of components, this study looked at Park and Chen (2012) study where they researched on the integration of PCK components in biology classes of four teachers working at the same high school. Park and Chen (2012) adopted the pentagon model of PCK (Park &

Oliver, 2008); consisting of five components. The study explored the nature of integration of components of PCK: (a) Orientations toward Teaching Science (OTS), (b) Knowledge of Student Understanding (KSU), (c) Knowledge of Instructional Strategies and Representations (KISR), (d)Knowledge of Science Curriculum (KSC), and (e) Knowledge of Assessment of Science Learning (KAs). The results of the study show that Knowledge of Science Curriculum (KSC) component did not integrate well with other components. However, Knowledge of Instructional Strategies and Representations (KISR) and the Knowledge of Student Understanding (KSU) were repeatedly integrated with other components. While reviewing PCK models which guide research studies), Friedrichsen et al., (2008) argue that there seems to be no explicit discussions on how constituent components interact. It is essential that the teachers' simultaneous use of components of PCK as efforts of enhancing learners' understanding becomes evident (Park & Chen, 2012). This study will also look at the integration of components between the TSPCK components of pre-service physical science teachers as a measure of quality displayed. This becomes the underlying focus in this study; consciously the congruency at both the planning and actual teaching contexts using the TSPCK episode and Mavhunga and Rollnick (2013) tsPCK model.

2.8 Measuring tsPCK

Measuring PCK can be challenging. tsPCK, as a version of PCK, also suffers the same challenges as PCK. So, it is not easy to capture it either. Rohan, Taconic, and Jochems (2009) argued that directly measuring a teacher's PCK is considered a challenge since this type of knowledge is difficult to transfer to another through written and verbal communication, and sometimes it is hard for teachers to verbalize their thoughts and beliefs. There are different ways used to measure tsPCK, just as different people use different instruments to capture tsPCK. For example, a study that was used to measure PCK was that conducted by Park and Chen (2012) where they researched on the integration of PCK components in biology classes of four teachers who were working at the same high school. In their study the researchers observed biology teachers teaching and video-taped their lessons. They also conducted pre-observation and post observation interviews and measured teachers' level of PCK using a rubric (Park & Chen, 2012). The PCK rubric was developed to measure teachers' PCK from data collected from various sources (Park & Oliver, 2008; Park, Yang, Chen & Jung, 2008).

Another tool that has been used to capture PCK is the Content Representation or CoRe instrument. CoRes are tools that attempt to portray holistic overviews of expert teachers' PCK related to the teaching of a particular science topic in a chart form (Hume, 2010). CoRes provide an overview of the content taught when teaching a particular topic and Pedagogical and Professional-experience Repertoires (Mulhall, et al., 2003; Loughran, Gunstone, Berry, Milroy & Mulhall, 2000). Each CoRe is accompanied by a suite of PaP-eRs, which are descriptions of how specific aspects of the topic aligned to the CoRe have been taught by the expert teachers (Hume. 2010). CoRes and PaP-eRs are considered the most useful method for eliciting PCK that is centred in a teacher's knowledge and pedagogical skills (Kind, 2009).

Mavhunga and Rollnick (2011) also developed a tool for measuring tsPCK. They employed the construct of TSPCK in investigating and developing both the in-service and pre-service teachers' PCK at a topic specific level; which was chemical equilibrium. The tool is used to score the Topic Specific PCK tool which is a rubric. The rubric corresponding to the five components of tsPCK was developed with each being rated on a four-point scale: 1(limited) to 4 (exemplary) (Mavhunga and Rollnick, 2011). Studies (e.g. Mavhunga & Rollnick, 2013, Judith, 2014) have employed the construct of tsPCK in investigating and developing both the in-service and pre-service teachers' PCK at a topic specific level.

This study attempts to measure the quality of tsPCK in teachers' planning and actual classroom teaching. It will use a rubric developed by Miheso and Mavhunga (2018). The rubric was developed in the context of capturing experienced teachers' enacted tsPCK episodes to score pre-service teachers' classroom teaching. The authors developed a three-point scale tsPCK rubric where 1 represents *basic* tsPCK episode, 2 represents *moderate* tsPCK episode, and 3 represents *proficient* tsPCK episode. The *basic* tsPCK episode provides a moment of only two tsPCK knowledge components being used interactively in explanation. The *proficient* or *developing* tsPCK gives a moment of the interactive use of three knowledge components. *Sophisticated* or *exemplary* tsPCK provides a moment of four knowledge components used interactively. The rubrics are of categories which describe the depth of teachers' understanding of the knowledge components regardless of the topic under investigation. The criteria in both rubrics emphasize the integration of knowledge components of tsPCK. A detailed discussion of the tool can be found in the methodology chapter.

CHAPTER 3

3. Methodology

3.1 Introduction

The theoretical framework used in this study is based on tsPCK and the research aims to find the congruency, if any, between lesson planning and enacted lesson in stoichiometry of the fourth year pre-service teachers in the physical science methodology class. An in depth qualitative method was used to carry out this research and the research was a case study. This is described in the chapter below.

3.2 Research Design

The study will employ a qualitative method research design that allows descriptive analysis of portrayed tsPCK quality. Qualitative research is defined as the naturalistic, interpretative, approach concerned with exploring phenomena from the interior and taking the perspectives and accounts of research participants as a starting point (Ritchie, Lewis, Nicholls & Ormston, 2013, p. 3). Anderson (2010) looked at the disadvantages of qualitative research and concluded that it is usually criticized as biased, small scale, anecdotal, and/or lacking rigor. However, the same author agrees that when it is carried out properly it is unbiased, in depth, valid, reliable, credible and rigorous. Anderson (2010) also argued that there are advantages in qualitative research. One of the advantages is that qualitative data is usually collected from a few cases of individuals so findings cannot be generalized to a larger population. However, the findings are transferable to another setting. This applies to this study because the data was collected from only four groups of participants and only three groups were selected for the study.

Qualitative research designs are just as systematic as quantitative designs, but they emphasize gathering data on naturally occurring phenomena. Most of these data are in the form of words rather than numbers, and in general, the researcher must search and explore with a variety of methods until a deep understanding is achieved. It is a way of knowing that assumes that the researcher gathers, organizes, and interprets information with his eyes and ears as a filter (Denzin

& Lincoln, 2011). In this study, this was done through analysis of a range of collected qualitative data.

3.3 Research Strategy – Case Study

A case study is one of numerous ways of carrying out research studies because it seeks to understand human beings in a social context by interpreting their actions as a single group, community or a single event (McMillan & Schumacher, 2014). It produces the type of context dependent knowledge that research, on learning, shows to be necessary to allow people to develop from rule-based beginners to skilful experts (Flyvbjerg, 2006). Case study research can be based on any mix of quantitative and qualitative approaches; it uses multiple data sources including two or more of direct detailed observations, interviews, and documents (Flyvbjerg, 2006).

Creswell (2012) refers to a case study as "an in-depth exploration of a bounded system (e.g., activity, event or individuals) based on extensive data collection" (p. 465). McMillan and Schumacher (2010) argue that being bounded implies the system is unique according to place, time, and other physical boundaries. The 'bounded system' in this study represents the case of a class of final year pre-service teachers. Punch (2009) then suggests the need for a case study researcher to identify and describe the boundaries of the case as clearly as possible. This study has boundaries, which makes it suitable to be a case study. The participating pre-service teachers are bounded by the fact that they were all fourth year students who were studying towards the same Bachelor of Education degree in physical science as their major subject in the same university for four years. The boundary conditions are fixed and will not change through the course of this study. A disadvantage of this approach, identified by Denscombe (2008), is that case study produces soft data because of its lack of strictness since it concentrates on qualitative and interpretative measures rather than quantitative ones which are measurable.

This study employed a case study of twenty four pre-service teachers located in a Physical Science methodology class. A case study is viewed as a useful tool for the beginning, exploratory stage of a research project and also as a basis for the development of the 'more structured' tools that are necessary in surveys and experiments (Rowley, 2002). This is a crucial tool to use in this study as it will give the researcher the opportunity of focusing on an in-depth qualitative exploration

(Creswell, 2013) of the relationship between the pre-service teachers' quality of tsPCK acquired in planning and that enacted in classroom practice.

3.4 Population and Sample

In this study, a class of pre-service physical science teachers who were in their final year in 2016 will represent the population, consisting of twenty (24) participants. The participants formed four groups and taught the lesson as a group. Only the work of three groups was chosen for data collection in this study. The fourth group was not chosen due to limited data that was found. Including the group would have limited the study or made it difficult to analyse the results. The groups worked closely with each other during the whole year and were never changed or separated.

The understanding was that this cohort of pre-service teachers will be employed as teachers in high schools by the Department of Education after they complete their Bachelor of Education degree. They will be expected to teach both physics and chemistry, as physical science – a term used to describe this school subject. The relationship between these pre-service teachers' quality of tsPCK acquired in their planning and that enacted in classroom practice will be explored in stoichiometry. The sample was selected because of the objective of the specific methodology course that cites the development of tsPCK in core topics of chemistry. The sample was therefore exposed, through the normal teaching of the course, to an intervention that aimed specifically at developing tsPCK in stoichiometry. The intervention followed the same structure as that reported in previous studies such as Mavhunga (2016) and Mavhunga and Rollnick (2013) but repeated here in brief whereby the participants were organized in 4 groups.

3.5 Intervention

3.5.1 Description of TSPCK Intervention activities

In this study, the program tagged *treatment* will be of an intervention that explicitly discusses the entire clue of transforming CK of a given chemistry topic, stoichiometry. As already indicated in the rationale, stoichiometry was the chosen topic of the intervention due to its importance as quantitative chemistry. The topic has also been reported to be problematic for teachers as they struggle with teaching it; thus impacting the learning and understanding of stoichiometry by learners (Feiman-Nemser, 2001),

The key feature of this intervention centres on the construct of tsPCK and how its knowledge components, once well understood, can be interactively engaged in transforming content knowledge (CK) of a given topic when thinking about and actually teaching the topic. The introduction of the construct tsPCK and its five specific-knowledge components was done with the participating pre-service teachers before conducting explicit discussions on each component. The intervention involved explicit discussions aiming to ensure the pre-service teachers' understanding of the knowledge components that enhance transformation of content knowledge in the topic of stoichiometry. It discussed the use of each knowledge component of tsPCK and how it interacts with others in formulating explanations for teaching the topic of the intervention.

The intervention was planned to discuss the understanding of each of the components of TSPCK in the physical science (chemistry) methodology course over a period of 5 weeks which was systematized into an overall of 10 sessions of 60 minutes each. Each week was designed to have three sessions organized into a period at the beginning of the week and a double period at the end of the week. The single period was used for the introduction of a particular tsPCK component and double period to develop understanding of how such could be used in transforming content knowledge of stoichiometry. The first period each week was planned to introduce a component of TSPCK. It consisted of teacher-learner centred discussions in which the participants were in their small groups to discuss on the TSPCK component in question. Such group discussions would last for about 15minutes after which the entire class shared their ideas and the lecturer would join in the discussion. Table 1 below displays the sequence in which the tsPCK components were discussed.

Table 3.1: The description of TSPCK Intervention Activities

Week	**Session**	**Focussed knowledge component**	**Intervention activities**	**Aspects of Content Knowledge focussed**
1	1	Administration of the notes on tsPCK and teaching of stoichiometry	Formal introductions of TSPCK construct and ethics issues	

	2	Learner Prior Knowledge	Extensive discussions and broad research into common learners' misconceptions in stoichiometry chemistry as in the literature. The pre-service teachers will be allowed to share their experiences and views on that. There will be group discussions on this, followed by a presentation of suggested teaching strategies to address the identified misconceptions. Where a strategy naturally draws on other tsPCK component, such moments were explicitly highlighted to the pre-service teachers.	- Calculations for volume, number of moles and molecular mass
2	3 and 4	Curricular saliency	Discussions were directed towards understanding that every topic, for instance, stoichiometry chemistry has 'big ideas' and 'subordinate concepts' that are important for the topic to be well understood. In addition, there was emphasis on sequencing of these ideas, awareness of the foregrounding concepts and understanding what is most important in each big idea. It was explained that the knowledge of a topic in terms of its big ideas, subordinate ideas, prior concepts, and sequencing is what is referred to as the 'curricular saliency'.	Big ideas: - Kinetic molecular theory - State of matter - Exothermic and endothermic reactions. Prior knowledge needed - calculations of molecular mass and number of moles

3	5 and 6	What is difficult to teach	Exploration of concepts considered difficult to learn, and identifying the actual issues that make understanding difficult. This was more than settling on the abstractness of concepts but pinpointing the actual difficulty. The pre-service teachers were made to understand that this is different from misconceptions but it refers to potential learners' difficulties in accurately understanding the full meaning of a big or subordinate idea. For example, practical meaning of limiting reagents.	- The concept of mole - Limiting reagents - Calculations in stoichiometry - Concentration at a microscopic level
4	7 and 8	Representations	Introduction of different levels of representations. This includes macroscopic, sub-microscopic and symbolic representations. There was emphasis placed concurrent use of these forms of representations in explaining each concept involved in stoichiometry.	Representing stoichiometry at molecular, structural and microscopic level
5	9 and10	Conceptual teaching strategies	Discussions emphasized and generated knowledge from other four knowledge components rather than general pedagogical and logistics.	Use of microscopic, macroscopic, and symbolic representations.

3.6 Research Instruments

3.6.1 Rubrics for scoring pre-service teachers' planned and enacted tsPCK

This study examines the congruency between pre-service teachers' tsPCK in two phases, as mentioned earlier: the planning phase, and the actual classroom-teaching phase. These two phases are considered as different contexts. For scoring pre-service teachers' tsPCK in the planning context, Mavhunga and Rollnick (2013) developed a rubric for the topic of chemical equilibrium. The rubric is used in this study (see Appendix 1) to score the pre-service teachers' written lesson plans about the stoichiometry topic. The rubric has the nature of being rated on a four-point scale

1; 2; 3; and 4: representing limited, basic, developing, and exemplary tsPCK, respectively. Each of these scale points is guided through the stated criteria for each component of tsPCK.

There will be no changes made to the criteria on each of the tsPCK components as they suited responses for the topic of stoichiometry in this study. Likewise, for scoring pre-service teachers' tsPCK in the actual teaching setting of the topic of stoichiometry, Miheso and Mavhunga (2018) developed a rubric. The rubric was developed in the context of capturing experienced teachers' enacted TSPCK episodes and it is adapted in this study (see Appendix 2) to score pre-service teachers' classroom teaching. The authors developed a three-point scale tsPCK rubric where 1 represents *basic* sPCK episode, 2 represents *moderate* tsPCK episode and 3 represents *proficient* tsPCK episode. The *basic* tsPCK episode provides a moment of only two tsPCK knowledge components being used interactively in explanation. The *proficient* or *developing* tsPCK gives a moment of the interactive use of three knowledge components. *Sophisticated* or *exemplary* tsPCK provides a moment of four knowledge components used interactively. A sample of this rubric is attached as Appendix 2. Both the rubrics by Mavhunga and Rollnick (2013) and Miheso and Mavhunga (2018) are similar in that they were constructed based on the five knowledge components of TSPCK construct. The rubrics are of categories which describe the depth of teachers' understanding of the knowledge components regardless of the topic under investigation. The criteria in both rubrics emphasizes the integration of the knowledge components of tsPCK.

	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 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 include conceptual scaffolding with reference to other TSPCK components
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.
Representat-ions	• 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

Figure 3.1: A rubric for enacted lesson plan

Type 1: **Basic TSPCK Episodes**	Type 2: **Proficient/Developing Episodes**	Type 3: **Sophisticated/exemplary Episodes**
• These are simple 2-component TSPCK Episodes. • The two components interacting are clearly, explicitly distinguishable • Both components work together to support an explanation of a single or a pair of concepts that are related	• These are 3- component TSPCK Episodes. • The three components interacting are clearly, explicitly distinguishable all being used at a single/one dimension level e.g. if it is representation sit will be only macro or symbolic or submicro. Or • That one of the three components is a component that is addressed implicitly based on the choice of representations or explanations • The three components work together to support an explanation of a single concept	• These are 4- component TSPCK Episodes with one of the components might or might not be repeated in the teaching segment or • The three components interact clearly, explicitly and are distinguishable, the repeated component is also distinguishable • The four components interacting are clearly, explicitly distinguishable • All four components work together to support an explanation of a concept • Three components evidently interacting and one being used at different representations all three being present

Figure 3.2: A rubric for enacted actual teaching

3.6.2 Video observation

This study will use unobtrusive observation with video recording capturing of pre-service teachers doing microteaching. The use of video recording in observations is beneficial in that it can be watched over and over again and then transcribed in order to provide rich data and check against any forms of misinterpretation or bias (Opie, 2004). Also, when observations are used as a research instrument, they are capable of producing *rich data* (Cohen et al., 2013) in such a way that the researcher can give full accounts of all that happened in the research field. That will permit the researcher the ability to report what they observe about the pre-service teachers' classroom practice. The limitation of observation with video recording, however, lies in that the people being observed may change their behaviour either consciously or unconsciously in the process (Opie, 2004).

3.7 Collection of Data

3.7.1 Collection of lesson plans and reflection reports

A group of 24 pre-service teachers participated in the data collection of this study. The teachers voluntarily agreed to plan lessons under the stoichiometry topic and to teach that topic. As mentioned, they were divided into four permanent groups where only three are regarded as a subsample for analysis. They planned and taught the lessons as a group. Their lessons were video recorded using a video camera. The participants also reflected on their work after planning and teaching and they submitted their reports that are part of the data used. In summary, in this study, three types of data were collected, the participants lesson plans, their video recorded enacted actual teaching, and their reflective reports on both planning and enacted teaching. The participants were given a week to plan for their stoichiometry lessons within their groups. The participants then taught their lessons in groups. There were four members in each group: one member would introduce the lesson, the other member would then teach the lesson with the help of the team especially in performing the experiment, and the last member would conclude the lesson. The teaching was a microteaching lesson whereby the participants were teaching their fellow class members. After teaching, they were given three weeks to write a report reflecting on their planning and teaching. The information, gathered during the classroom teaching, served as the data for describing pre-service teachers' demonstrated tsPCK and learners' conceptual understanding. The reports served as additional information that helped to find out what the participants thought of their planning and teaching; reflecting on where they went wrong and what the reasons were.

3.7.2 Collection of captured tsPCK in actual lesson delivery

This study used unobtrusive observation with video recording capturing of pre-service teachers doing microteaching. The use of video recording in observations is beneficial in that a video can be watched several times and then transcribed in order to provide rich data and check against any forms of misinterpretation or bias (Opie, 2004). Also, when observations are used as a research instrument, they are capable of producing *rich data* (Cohen et al., 2013); in such a way that the researcher can give a full account of what happened in the research field. In this particular study, this will allow the researcher to report what they observed about the pre-service teachers' classroom practices (Bertram & Christiansen, 2014).

3.8 Data analysis

Data from the three participating groups were analysed using the qualitative in-depth analysis method for explicit tsPCK (Park & Chen, 2012). In the teaching segment, this researcher was looking for a tsPCK episode. A teaching segment can be a portion of a lesson where there is a tsPCK episode or there is a portion of the actual lesson delivered where this researcher saw evidence of the tsPCK episode. A TSPCK episode is defined as a moment where two or more components of TSPCK demonstrated in a specific teacher task segment (Mavhunga, 2015). This researcher identified the episodes with the help of a rater to improve trustworthiness. Once the episode is identified, each tsPCK episode was then described in detail in terms of; (i) what the pre-service teacher had written; (ii) what components are at play; (iii) what structural layout is depicted by the manner the components relate to each other; and (iv) the nature of teacher tasks in which the TSPCK episode emerged. The episode was then presented through an analytic device called a *TSPCK MAP,* an idea adapted from Park and Chen (2012). A tsPCK MAP, was defined as a visual pictorial diagram describing connections between components identified in a tsPCK episode (Park & Chen, 2012).

For simplicity purposes, the components of TSPCK have been abbreviated as follows: Learner Prior Knowledge referring to common misconceptions = LP; Curricular Saliency = CS; what is difficult to understand = WD; Representations = RP, and Conceptual teaching strategies as CTS. Figure 4, below, provides an example of a TSPCK Map that could represent a TSPCK Episode. A detailed description is given in Figure 3.3 to illustrate how the TSPCK maps were constructed.

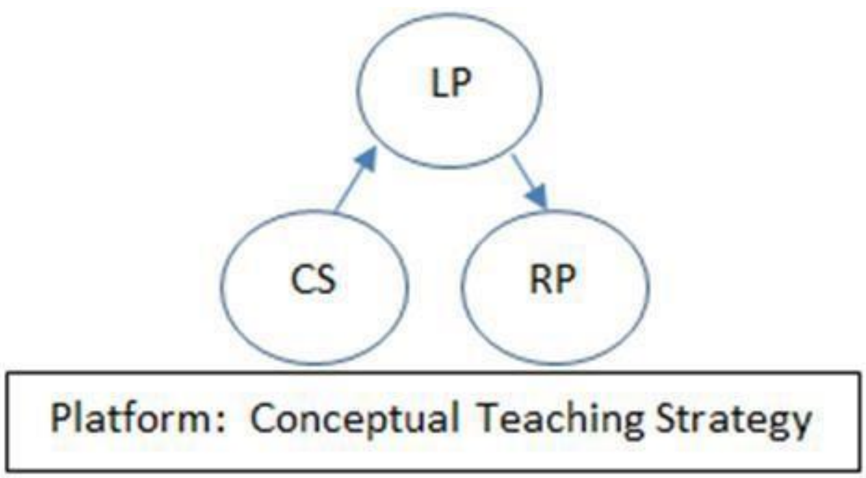


Figure 3.3: An example of a tsPCK map

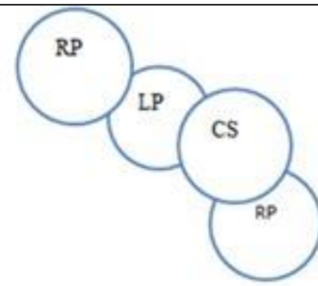
In this map, there are three components of tsPCK: curricular saliency (CS), Learner Prior Knowledge (LP), and Representations (RP). The lines between the components represent evidence of a link between the components. The direction of the arrows indicates the arrangement in which components appear in a TSPCK episode. The platform at the base of the identified components indicates the type of the teacher task in which the tsPCK episode emerged.

The platform on which the identified components stand indicated the type of the specific teacher task from which the tsPCK episode emerged. For example, the tsPCK map shown in Figure 3.4 was interpreted to mean that the observed tsPCK episode emerged from a response explaining the conceptual teaching strategy to be used. The component of LP was seen at the beginning of the episode; it seemed to have been dealt with before moving-on into a discussion that referred to representations (RP) and an aspect on curricular saliency (CS) interactively.

3.8.1 Analysis of lesson plans on stoichiometry

From the groups' lesson plans, tsPCK episodes were identified and analysed using the tsPCK rubric by Miheso and Mavhunga (2018). In practical terms, the criteria for the tsPCK component of conceptual teaching strategies (CTS) was found to be more relevant and it was the only criteria used for analysing lesson plans. The criteria of CTS readily spoke to the lessons plans as they were a reflection of suggested teaching strategies for the topic of stoichiometry. The reason why the component teaching strategy was chosen is that it consists of all the components in the TSPCK model. For example, when teaching about stoichiometry, it is useful to identify a concept like concentration and to discuss how the concentration of substances differs due to different concentrations by using representations at all three levels at the same time. The teacher would also use a certain strategy to find the learners' prior knowledge and also teach them about the concept which is the curricular saliency. So, all the 4 components can be found in the conceptual teaching strategies depending on the teacher's planning. Miheso and Mavhunga (2018) refer to other tsPCK components that needed to be considered in the formulation of a conceptual teaching strategy. After matching the criteria in the rubric, a TSPCK MAP was constructed to reflect the nature of the episode. For example, the following tsPCK episode was identified from the lesson plan of Andile's group. This extract was taken from Andile's lesson plan, under the heading *Sequence to be followed in a lesson.* Sequencing of a lesson is regarded as a task associated with the actions that a teacher does when planning a lesson. The lesson was based on the conceptual teaching strategy suggested for *stoichiometry* under the concept of *concentration*.

Table 3.2: An example of a rated lesson plan by three raters.

Extract from the lesson plan	Here analysis done	TSPCK MAP
I will bring a glass half-filled with a juice, show it to the learners, and ask them to imagine the juice with 10 particles in it, and then add water to it. At this point, I will ask the learners to draw the number of particles that they think will be present in the juice after adding water and how they will be positioned……. One of the expected answers from the learners is the weakness and how strong the other juice is compared to the other, which is concentration. The teacher will use this answer as a point of departure from which he is going to explain the concept of concentration thoroughly.	The extract contains a TSPCK episode as it reflects considerations of knowledge from more than two tSPCK components. The first is an element of the component of macroscopic representation evident from the consideration of showing learners a glass of juice and asking them to imagine that there are 10 particles in it. The second is learner prior knowledge where the learners were asked to draw the number of particles that they think will be present after the juice has been diluted. The third is the evident curricular saliency whereby the teacher will take the answers of the learners to explain to them about concentration.	

3.8.2 Analysis of corresponding video-recorded lessons on stoichiometry

For the analysis of tsPCK in action in the real classroom, the teaching segments were the recorded video lessons. In a similar fashion, this researcher identified tsPCK episodes with the help of a rater to increase trustworthiness. This involved this researcher finding episodes in the lesson plan and also determining the quality of each episode found in the lesson plan using a rubric by Miheso and Mavhunga (2018): *basic* being score 1 and *exemplary* 4 (Figure 3.3). According to this approach, the interactive presence of two or more components of tsPCK, demonstrated on a segment of an enacted lesson plan as a planning document and enacted actual teaching, was first identified and labelled as a *tsPCK episode*. A planning document such as a lesson plan may have a few specific portions where the descriptions given contain a tsPCK episode. An example of a segment that contained a tSPCK episode extracted from a planning tool is demonstrated below.

Table 3.2: an example of a rated video recorded enacted lesson by three raters.

Extract from the lesson plan	Here analysis done	TSPCK MAP
Teacher: If we are not given the amount of a substance, let us say for instance we are given the mass of that substance. How will that affect the concentration? Here I have two substances (picking up the two substances) I have potassium dichromate here and then on this one I have copper sulphate. Before the class, I have measured these two, 2 grams and then two grams this side (showing them substances). So we are going to create a solution out of this one and see. Since the solutions have the same mass, do you think they are going to have the same concentration? That is what we are interested in. But while I am doing that (making solutions) can you guys wrap your minds around this and tell me if they are going to have the same concentration or it will be different concentration. .	The teacher first started with a conceptual teaching strategy for understanding concentration of two different substances (Potassium dichromate and Copper Sulphate) with same mass dissolved in the same volume. He came up with a macroscopic representation of these two substances and demonstrated them to learners. While demonstrating to learners, he checked for their prior knowledge by asking them which substance they think would have more concentration.	

In summary, the following section explains the data and analysis for the listed research questions in this study.

3.8.3 Answering Research Question 1

To answer Research Question 1, which is about the lesson plans that were written by the participants as described above, this researcher analysed the lesson plans to see if there are any tsPCK episodes and how many of the episodes are found in each lesson plan. The researcher then scored the quality of the lesson plans using TSPCK rubric (Miheso & Mavhunga, 2018). The rubric is structured according to four categories that will display the quality of each lesson plan episode. Two other raters were used to help improve the reliability of the results and put the scores generated in rubric. Each of them separately looked for the episodes in the lesson plans, rated the quality of each episode using the rubric, and then compared their analysis. If the scores and quality were different, they consulted the rubric to see why they were different and then reached a consensus.

3.8.4 Answering Research Question 2

To answer Research Question 2, which is about tSPCK in practice, considered as enacted tsPCK (etsPCK), this researcher analysed videos through in depth qualitative analysis (Park & Chen, 2012). This required identification of moments when 2 or 3 components of TSPCK are used in an explanation on an instant. The presence and connections between components, found in a TSPCK Episode, are indicated in the analytic device called a *tsPCK Map*, adapted from Park and Chen (2012). These moments are called *TSPCK episodes*, which make up TSPCK maps. A TSPCK Map describes connections between two or more components used in defining TSPCK (Mavhunga, 2015). Thus the focus of the analysis of the *TSPCK Episode* will be on the nature of the interactions of the components.

3.8.5 Answering Research Question 3

To answer Research Question 3 about relationship between planned vs. enacted TSPCK this researcher compared the analysis from Q2 to Q3 in order to find the relationship between the pre-service teachers' quality of TSPCK acquired in planning and that enacted in classroom practice (Shulman, 1986). This researcher also compared the identified and verified tsPCK components for: (i) quantity of tsPCK episodes identified whereby the researcher examined how many episodes are in each lesson; (ii) whether the tsPCK episode in the lesson plan is evident (without any doubt) in the recorded video lesson; (iii) the format of the tsPCK episode in which the sequence of components occur in the lesson plan and also in the recorded lesson. The findings are recorded in Chapters 4 and 5.

3.9 Validity and Trustworthiness

Suter (2011) says that the most important criterion for judging the quality of a qualitative study is its credibility. Sharing the same view, Merriam and Tisdell (2016) refer to the internal validity (otherwise known as *credibility*) as the definite strength of qualitative research. Validity means measuring what is intended. The idea of defining TSPCK episodes and using tsPCK maps has been used in several studies and is able to reflect quality of TSPCK. Hence their use in this study is based on what is established and validated (Mavhunga, 2015; Park & Chen, 2012). Trustworthiness refers to the quality of both findings and data and is said to have four components being: credibility, transferability, dependability, and conformability (Letts et al., 2007). To insure reliability or trustworthiness this researcher used different data sources such as the reflection reports to confirm identified TSPCK episodes and also worked with a reference team of two experienced people who have worked in the TSPCK field to confirm identification of TSPCK episodes; according to established definition of episodes.

3.10 Ethical Consideration

Application for ethical clearance was completed and taken to the University of Witwatersrand ethics committee team. Ethics is defined by Gajjar (2013) as a method, procedure, or perspective for deciding how to act and for analysing complex problems and issues. In this research, ethical consideration was carried out in a manner that the participants' personal information was confidential. This requirement is observed by writing to members of this class. The consent form explained to them what the research is about, how it will benefit them and the researcher, and that there will be total confidentiality when it comes to their personal information such as names and student numbers. The names Themba, Mavis, and Andile used to identify the groups are pseudonyms and do not represent the actual names of the participating pre-service teachers. Many of the ethical norms help to ensure that researchers can be held accountable to the public (Gajjar, 2013).

The participants were informed that if they wish not to continue with the research they can pull out anytime without any consequences and explanation. Ethical rules promote the aims of research, such as knowledge, truth, and avoidance of error such as prohibitions against fabricating, falsifying, or misrepresenting research data; they promote the truth and avoid error (Gajjar, 2013).

CHAPTER 4

4 ANALYSIS OF ENACTED tsPCK in LESSON PLANNING

4.1 Introduction

This chapter provides a response to the first research question that looks at the quality of TSPCK in the lesson planning. This question was explored using a qualitative method called the qualitative in-depth analysis (Park & Oliver, 2008a). In exploring this question, data was collected from pre-service teachers at the end of the intervention in a form of submitted reports on reflections containing sample lesson plans on stoichiometry. As indicated in Chapter 3, the analysis followed an in-depth analysis of tsPCK episodes. A tsPCK episode was presented, in Chapter 3, as a moment where two or more components of tsPCK are seen working together interactively in a specific teacher task segment (Mavhunga, 2015). A teacher task segment is a portion in a lesson plan, or a moment in the actual delivery of the lesson, where a tsPCK episode is observed. In other words, a tsPCK episode signifies the pre-service teachers' moment demonstrating understanding of the interactive use of two or more tsPCK components in teaching. The first step in this analysis, was to identify, with reliability, the tsPCK episodes present in a lesson plan. The assistance of two independent raters was used to confirm this researcher's identification. The second step followed was to describe the tsPCK components present in the identified tsPCK episodes as well as the sequence in which they emerged. The components found present in the tsPCK episode and their sequence of appearance were drawn pictorially using a tsPCK map. As explained in Chapter 3, a tsPCK map presents the tsPCK components that are there and how they are interacting with each other (either in an interwoven or in linear form). From the observed nature of the interactions, the quality demonstrated could be matched to a quality category in the tsPCK rubric used in this study as shown in the Appendix 1. Table 1 below presents an overview of the quantity and nature of tsPCK episodes found in the lessons plans from the three groups of pre-service teachers explored. Each group produced 1 lesson plan on the topic of intervention: stoichiometry. The lesson plans covered different concepts in stoichiometry such as concentration (1 group) and limiting reagents (2 groups).

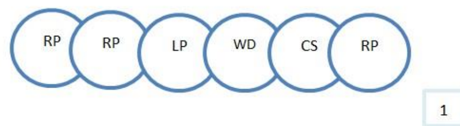
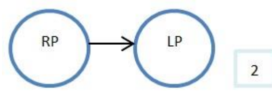
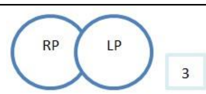
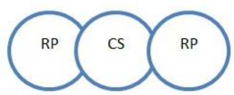
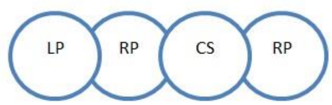
Pre-service teachers group	Total TSPCK episodes in lesson plan	Corresponding TSPCK maps	Quality of TSPCK Episodes		
Andile's group	3		**Episode1** Exemplary	**Episode 2**	**Episode 3**
				Basic	
					Basic
Mavis's group	2		Developing	-	-
Themba's group	1		Exemplary	-	-

Table 4.1: An overview of tsPCK episodes found in the lesson plans on stoichiometry

Table 4.1, above, provides an overview of the findings of the analysis of individual groups. Each group was treated as a case. Table 1, above, shows that the groups generated lessons plans with varying quantity and nature of tsPCK episodes. The number of episodes decreased across the groups, where the first group had three episodes, the second group had one episode, and the last group had one episode. Andile's group had the most number of tsPCK episodes. Their lesson plan had a total number of three tsPCK episodes with one episode being exemplary and two falling into the basic category of the rubric. Mavis' group had two tsPCK episodes and both of the episodes were allocated into the basic category in the rubric. Meanwhile, Themba's group had one episode which was an exemplary tsPCK episode. While, the quantity of tsPCK episodes present in a lesson is positive desirable evidence, the quality of the tsPCK episodes is most desired. That is, it is noted that Mavis's group had two tsPCK episodes which were however of a lower quality (basic). Furthermore, Themba's group had much fewer tsPCK in quantity but the one that existed was in the exemplary quality category.

4.2 Integration of tsPCK components in lesson planning

Following, below, is a qualitative narrative of the description of the content of the teaching segment from Andile's lesson plan. This lesson plan contained a tsPCK episode which had the highest number of components interacting (exemplary). In this lesson plan, Andile and his three colleagues were planning to teach a lesson on the topic called stoichiometry. The planning is for an introductory part of the lesson.

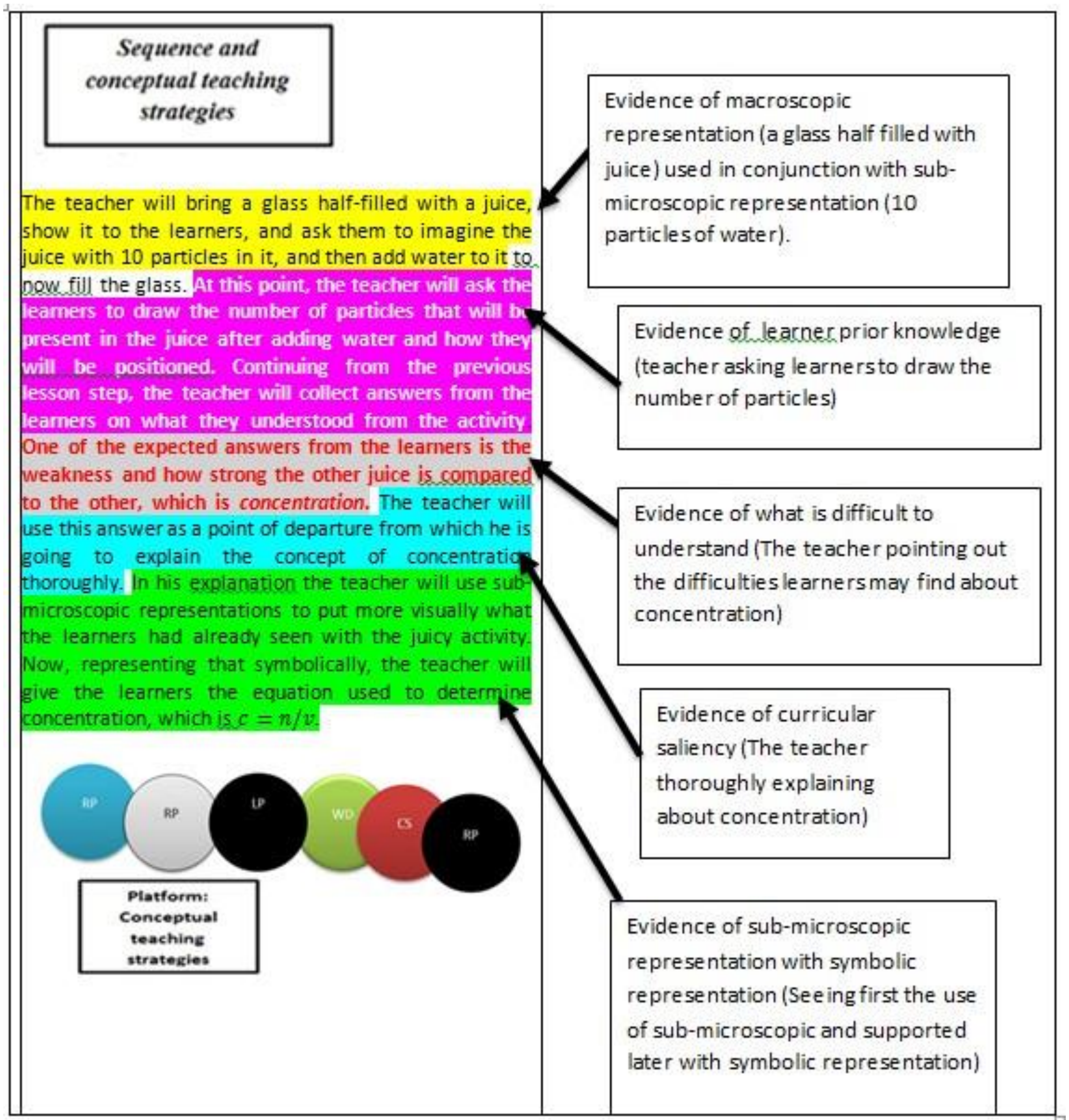


Figure 4.1: Andile's group tsPCK episode and corresponding TSPCK map extracted from their lesson plan.

Andile's group prepared their lesson on introducing the concept of *concentration*. The group provided a definition on concentration as the "abundance of a constituent divided by the volume of the mixture" (Brown, 2015). Andile's group planned to provide learners with a macroscopic representation (RP) of a glass half filled with juice. The students are told to imagine the juice with 10 particles in it, and then add water to it to now fill the two glass containers with the same colourful juice whereby they will identify the juice with a high concentration from the other. The group then planned on asking learners to draw the number of particles that they think would be present in the juice after dilution. That is a tsPCK concept of learner prior knowledge whereby the teacher is gathering the information that learners might have. It is expected that some the information from the learners will be correct and some of it may be misconceptions. The group said that "one of the expected answers from the learners is explaining the weakness and how strong the other juice is compared to the other, which is *concentration*". That is a tsPCK component of what is difficult to teach (WD). The group expected learners to find the concept of concentration difficult to understand. This is a potential difficulty as learners commonly experience difficulties in mastering the concept of dilution; the effect of volume on concentration. The reasons provided in their submitted reflection report point to the use of the representation and learners' answers in order to explain to them what concentration is and how it is affected by a changing volume because learners might understand what concentration is but they might not understand what dilution is. Andile's group planned to use what the learners would find difficult regarding concentration to thoroughly explain the concept of concentration. That is a tsPCK component of curricular saliency, which is the emphasis of a concept.

The last two tsPCK components that are visible in the planning are sub-microscopic representation and symbolic representation. The group planned to "use sub-microscopic representations to put more visually what the learners had already seen with the juice activity" and they showed a glass of juice with a glass of water whereby the juice would be diluted with water as seen in Figure 4.1 above. The comments from the group indicated that in addition to introducing the basic understanding on stoichiometry, they also wanted to ensure a visualization of the impact of volume on concentration, so that learners understand the equation for calculating concentration. The last episode demonstrated by the group is a symbolic representation where the teacher planned on giving learners the equation of calculating for concentration, meaning that when they are done with explaining the concept of concentration, learners can now do calculations and find out how much concentration is found in a substance.

Their suggested introduction presented a teaching segment that integrated the use of the tsPCK component of representations with that of what *is difficult to understand* as learners commonly experience difficulties in mastering the understanding on the concept of dilution; the effect of volume on concentration. The reasons provided in their submitted reflection report point to the use of the representation and learners' answers in order to explain to them what concentration is and how it is affected by a changing volume. The teacher segment in the groups' lesson plan continued to describe the next steps to include the teacher's use of sub-microscopic representations along with symbolic representations in their explanations of concentration and its influence by volume. The group inserted a picture shown below; in Figure 4.2.

The comments from the group indicated that in addition to introducing the basic understanding on stoichiometry, they also wanted to ensure a visualization of the impact of volume on concentration, so that learners understand the meaning in the equation for calculating concentration.

The presence of the two or more components in the same sentence signals an interwoven interaction of the components (Mavhunga, 2015). In this episode the teacher is demonstrating a tsPCK episode with 4 different interwoven components with one (1) component (representations) repeated. The existence of the different tsPCK components is shown by the different sentences found in the tsPCK episode. For example, the component of representations is first evident in the sentence, "I will bring a glass half-filled with a juice, show it to the learners, and ask them to imagine the juice with 10 particles in it, and then add water to it". According to the plan, here the teacher is using macroscopic representation in conjunction with sub-macroscopic representation. The next different tsPCK component is Learner Prior Knowledge (LP), shown in the sentences which are representations (RP), where the teacher wanted to use the representation of two juices with different concentration in order to get learners' prior knowledge about concentration. In Figure 4.1, words highlighted in yellow show what the teacher said about the macroscopic representation component. The learner prior knowledge is interwoven with representation, which is used to identify their knowledge about concentration. That is because the teacher said that he would use the representation of diluted juice and ask learners to draw the number of particles that they think are in the juice. Therefore, the teacher was trying to find out the learners' prior knowledge by using the macroscopic representation. That is why the learner prior knowledge and representation are interwoven. The learner prior knowledge is then integrated with curricular saliency whereby Andile's group planned to use the learners' answers to explain the concept of concentration. They said that "…will use this answer as a point of departure from which he is going to explain the concept of concentration thoroughly." This refers to instances when they had to teach about concentration which is the curricular saliency. The last component in the episode is sub-microscopic representation where Andile said that the process of explaining would employ a symbolic representation. That would show them how to calculate for concentration: "teacher will give the learners the equation used to determine concentration, which is $c = n/v$." The equation that the group planned to use is a symbolic representation which is interwoven with curricular saliency as the teacher used the concentration concept to explain how learners can do their calculations.

A different case, with a developing tsPCK episode, is captured in a context where Mavis's group provided teaching strategies for their lesson on limiting reagents as shown in Figure 4.2 below. In this case, Mavis and her colleagues were planning to introduce a lesson on limiting reagents. The extract shown in figure 4.2 is taken from their lesson plan under the heading *conceptual teaching strategies*. An explanation of the extract is given in Figure 4.2 below.

Sequence and conceptual teaching strategies

Dance analogy
Introducing a concept
Perform a demonstration using one reactant becomes entirely consumed and the other reactant is left over. The reactant that becomes consumed is called the limiting reagent. When the limiting reagent is allconsumed, no more products can be formed (reaction complete). The reactant limits the amount of product that can be formed
At the end, the teacher and the learners will calculate for the limiting reagent in the chemical reaction they have performed, **thus using the symbolic level of representation to engage with the learners by asking them questions and finding out if they understand.**

Evidence of macroscopic representation (Performance of an experiment where one reactant is a limiting reagent and the other is in excess)

Evidence of curricular saliency (Emphasis on the limiting reagent component which is the topic for the lesson)

Evidence of symbolic representation (Calculation for limiting reagent).

Figure 4.2: Mavis'group's tsPCK episode map with the extract from the lesson plan.

Mavis' group prepared their lesson on limiting reagents; a concept in stoichiometry. Limiting reagents are defined as substances that are totally consumed when a chemical reaction is complete (Brown, 2015). Mavis group's lesson was found to have one episode. The first episode had two tsPCK components. The first component is representation (RP) which is highlighted in green in Figure 4.2 whereby the group said that they will start off the lesson with an experiment on limiting reagent where two reactants will react and the other one will get consumed first in order to show that the consumed product is the limiting reagent. The representation component interacts with curricular saliency (CS). According to the group, "The reactant that becomes consumed is called the limiting reagent. When the limiting reagent is all consumed, no more products can be formed (reaction complete). The reactant limits the amount of product that can be formed." The curricular saliency is highlighted with black.

Mavis' group planned to teach learners how to do calculations in order to find the limiting reagents using different methods to find the limiting reagents. This is a demonstration of symbolic representation. According to Treagust et al. (2003), the calculations are seen as the symbolic representation. As shown in Figure 4.2, the representation component is highlighted with blue; whereby the group said that they planned for the teacher to calculate for the limiting reagents, "At the end, the teacher and the learners will calculate for the limiting reagent in the chemical reaction they have performed." The presented teacher task from the group was seen to have an integration of three tsPCK components: macroscopic representation (RP), learner prior knowledge (LP), and symbolic representation. Hence it is graded to be in the developing category.

The last group (Themba's group) planned to teach about concentration, which is a concept under stoichiometry. There were also four of them in the group. The extract (Figure 4.3) is taken from their lesson plan under the heading *conceptual teaching strategies*. An explanation of the extract is given under the Figure 4.3.

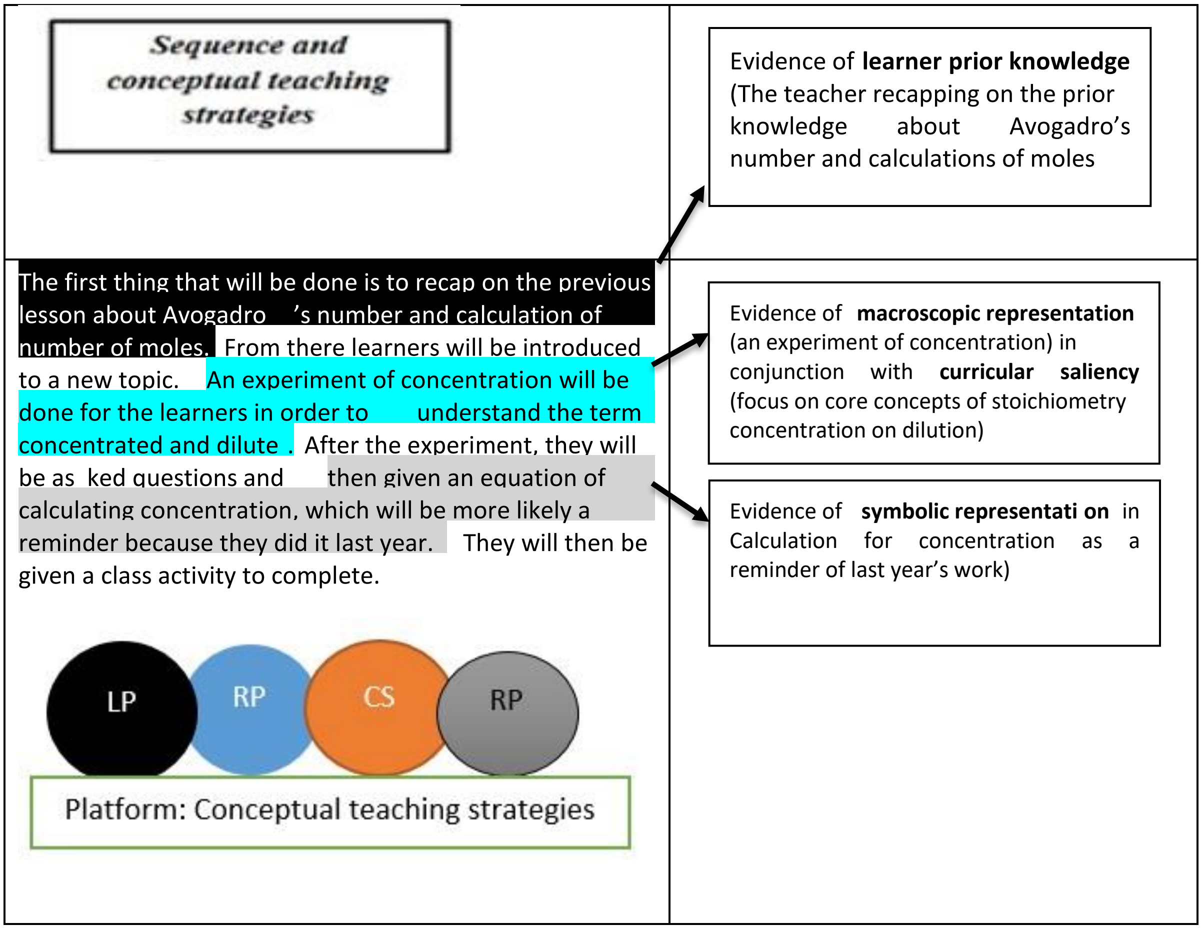


Figure 4.3: Themba's group's tsPCK episode map with the extract from the lesson plan.

This lesson only shows one episode that has four components. Themba's group mentioned that they would start with recapping on the previous lesson on Avogadro's number. They decided to recap on a previous lesson in order to see if learners have any misconceptions or misunderstanding that might affect their understanding of concentration. This is shown in Figure 4.3; "The first thing that will be done is to recap on the previous lesson about Avogadro's number and calculation of number of moles". The learner prior knowledge component is exposed in that sentence. They said that, from there, they will give learners an experiment that would help learners to understand dilution and concentration. That shows two concepts working together; meaning that the group would use an experiment in order to help learners to understand a concept. That is a concept of macroscopic representation interwoven with curricular saliency. The last component seen is symbolic representation where learners were going to be given calculations on the topic and taught how to carry them out. That component is seen when the group said learners will be "given an equation of calculating concentration, which will be more likely a reminder because they did it last year." The calculation of concentration is a symbol for symbolic representation. There are four components found in this lesson plan. Learner prior knowledge is interwoven with macroscopic representation, which is in conjunction with curricular saliency and is interwoven with symbolic representation.

Themba's group started their lesson planning by recapping on the previous lesson about Avogadro's number and calculation for the number of moles, which is macroscopic representation (RP). They then moved on to give learners examples of calculations on concentration and then asked them to also do the calculations in order for them to understand concentration and dilution. That shows an integration of symbolic representation with curricular saliency whereby the teacher would use the symbolic representation to elucidate the core concept of the lesson: concentration and dilution. The last episode is *representation*; where the group planned to teach learners about calculations for concentration.

4.3 Summary

In summary all the three lesson plans have different quantities of tsPCK episodes which have different qualities. The difference in quantities of tsPCK episodes seen in the groups is desirable. However, more emphasis is placed on the quality of the observed episode as an indicator of the teacher professional knowledge that the pre-service teachers have. Exemplary tsPCK episodes provided insight on the nature of interactions of multiple components generated in a teacher task segment. The Chapter analyses for tsPCK episodes in the implementation of the lesson plans analysed in this chapter, and looks for congruency with the generated plans.

CHAPTER 5

5 ANALYSIS OF ENACTED tsPCK IN THE ACTUAL LESSON DELIVERY

5.1 Introduction

This chapter delivers a response to a research question that looks at the nature of TSPCK evident in the pre-service teachers' actual classroom teaching of stoichiometry; based on the lesson plans developed and analysed in Chapter 4. In the same manner as the analysis of lesson plans in Chapter 4, this researcher analysed for tsPCK episodes evident in the video recorded lessons on stoichiometry. In this case, the teaching segments were moments in the actual teaching where the teacher was seen to demonstrate the verbal or action or combination evidence of tsPCK component interactions. Table 5.1, below, provides an overview of the analysis from the three video-recorded lessons.

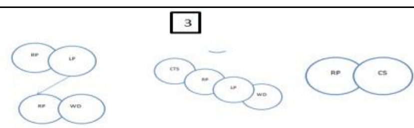
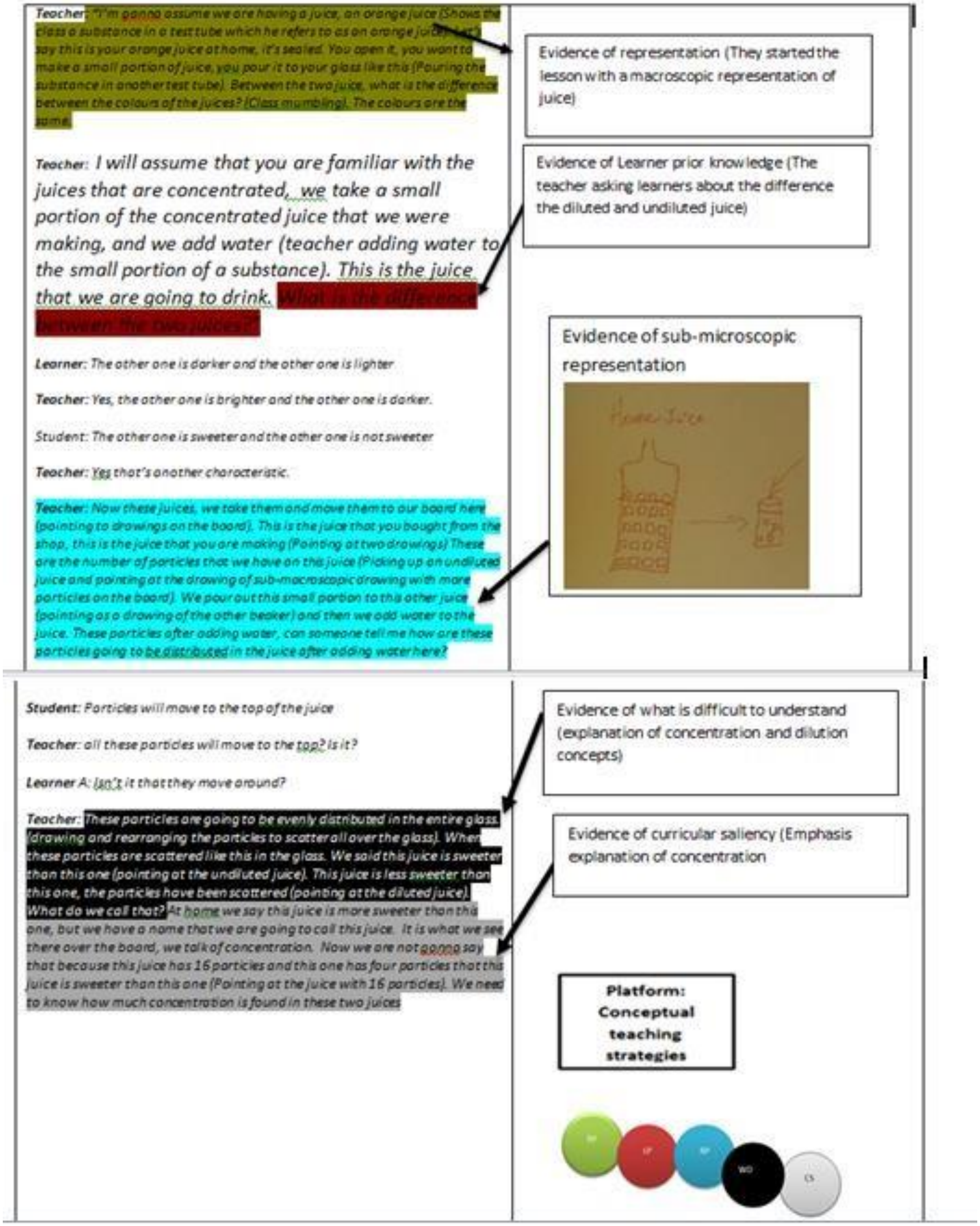
Pre-service teacher	Total TSPCK episode	tsPCK maps	Quality of tsPCK maps		
Andile's group	3		Episode 1	Episode 2	Episode 3
Mavis' group	1				
Themba's group	1				

Table 4.2: An overview of tsPCK episodes found in the enacted lesson on stoichiometry

Table 4.2, above, provides an overview of findings from the individual groups' analysis. Each group was treated as a case. The table shows that the groups taught lessons with varying tsPCK episodes. All groups have different numbers of episodes of different quality; where at least each teacher had an integrated episode. All groups showed episodes that have multiple components clustered together. In cases where the identified episodes are more than one, they were close to each other as a cluster of episodes. The number of episodes from each group became less with the first teacher having three episodes, the second teacher, and the last group with one episode each. Andile's group had more episodes than the two groups. It had three teaching episodes: the quality of the first episode was developing, the second episode was exemplary, and the third episode was basic. Mavis' group had one episode; with an exemplary quality. Themba's group had only one tsPCK episode; with an exemplary quality.

5.2 Integration of tsPCK components in the actual lesson delivery

Four different teachers taught the lesson in Figure 5.1. It is called Andile's group because Andile introduced the lesson. The lesson is about the concentration concept found in stoichiometry topic in chemistry. Each teacher took a turn in teaching the lesson. The extract below shows a teaching segment where the teachers were introducing the topic.



Teacher: "I'm gonna assume we are having a juice, an orange juice (Shows the class a substance in a test tube which he refers to as an orange juice) Let's say this is your orange juice at home, it's sealed. You open it, you want to make a small portion of juice, you pour it to your glass like this (Pouring the substance in another test tube). Between the two juice, what is the difference between the colours of the juices? (Class mumbling). The colours are the same.

Evidence of representation (They started the lesson with a macroscopic representation of juice)

Teacher: *I will assume that you are familiar with the juices that are concentrated, we take a small portion of the concentrated juice that we were making, and we add water (teacher adding water to the small portion of a substance). This is the juice that we are going to drink. What is the difference between the two juices?*

Evidence of Learner prior knowledge (The teacher asking learners about the difference the diluted and undiluted juice)

Learner: *The other one is darker and the other one is lighter*

Teacher: *Yes, the other one is brighter and the other one is darker.*

Student: The other one is sweeter and the other one is not sweeter

Teacher: *Yes that's another characteristic.*

Teacher: *Now these juices, we take them and move them to our board here (pointing to drawings on the board). This is the juice that you bought from the shop, this is the juice that you are making (Pointing at two drawings) These are the number of particles that we have on this juice (Picking up an undiluted juice and pointing at the drawing of sub-macroscopic drawing with more particles on the board). We pour out this small portion to this other juice (pointing as a drawing of the other beaker) and then we add water to the juice. These particles after adding water, can someone tell me how are these particles going to be distributed in the juice after adding water here?*

Evidence of sub-microscopic representation

Student: *Particles will move to the top of the juice*

Teacher: *all these particles will move to the top? Is it?*

Learner A: *Isn't it that they move around?*

Teacher: *These particles are going to be evenly distributed in the entire glass (drawing and rearranging the particles to scatter all over the glass). When these particles are scattered like this in the glass. We said this juice is sweeter than this one (pointing at the undiluted juice). This juice is less sweeter than this one, the particles have been scattered (pointing at the diluted juice). What do we call that? At home we say this juice is more sweeter than this one, but we have a name that we are going to call this juice. It is what we see there over the board, we talk of concentration. Now we are not gonna say that because this juice has 16 particles and this one has four particles that this juice is sweeter than this one (Pointing at the juice with 16 particles). We need to know how much concentration is found in these two juices*

Evidence of what is difficult to understand (explanation of concentration and dilution concepts)

Evidence of curricular saliency (Emphasis explanation of concentration

Platform: Conceptual teaching strategies

Figure 5.1: Andile's tsPCK Episode and a corresponding TSCK Map

The extract above presents the TSPCK episode with an extract of a lesson in stoichiometry taught by Andile's group. Andile's group was teaching a lesson on concentration which is a concept from the stoichiometry topic. The TSPCK map shows an integration of two components which are connected in a linear structure with other three components which are also interwoven. The first identified component in the episode is representation (RP) which interacted with the learner prior knowledge. The representation was macroscopic, as shown in the sentence:

> I'm gonna assume we are having a juice, an orange juice (Shows the class a substance in a test tube which he refers to as an orange juice). Let's say this is your orange juice at home, it's sealed. You open it, you want to make a small portion of juice, you pour it into your glass like this", (Pouring the substance in another test tube).

According to Treagust, Chittleborough, and Mamiala, (2010), the macroscopic level is the observable chemical phenomena: experiments results that learners can observe such as colour changes and observing new products being formed and others disappearing. The representation was an experiment, a dilution of a substance which learners needed to understand as a pre-concept of concentration.

Using this representation, the teacher asked the learners a question on the difference between the diluted and the undiluted juice. The sentence is highlighted with read in Figure 5.1. The teacher used the learner prior knowledge (LP) to correct any misconceptions that learners had about concentration and also used that pre-concept as the foundation to teach learners about concentration.

> I will assume that you are familiar with the juices that are concentrated, we take a small portion of the concentrated juice that we were making, and we add water (teacher adding water to the small portion of a substance). This is the juice that we are going to drink. What is the difference between the two juices?

This question was used to lead to the explanation of the concentration concept; meaning that learners should be able to differentiate between substances of different concentration. The evidence of two concepts (representation (RP) and learner prior knowledge (LP)) in the same sentence shows the integration of the two concepts. This helped the learner to understand the concept of concentration better through the macroscopic representation and questioning.

When Andile's group had gotten the foundation for the concentration concept, they gave learners a sub-microscopic representation of the experiment. This was done through showing the learners a drawing of the particles of the diluted and undiluted juice to elicit the concept of dilution and the amount of a substance (n). The sub-microscopic level of representation is used to explain the macroscopic phenomena in terms of the movement of particles such as electrons, molecules, and atoms (Treagust et al., 2010). The teacher used this representation (RP) in order to help students understand the macroscopic concept of concentration in a microscopic way because it is very difficult for people to explain things that they cannot see, such as taste, colour or extent of sweetness back to concentration. The RP component is interacting with *what is difficult to teach* component (WD). The component WD is linking with the macroscopic representation whereby the teacher shows learners the juice, changes the volume and then links it with the particles of the juice. So, it is the link that shows the impact of change of concentration, volume, number of particles, and the macroscopic (what you see) as an effect of change in concentration. Figure 5.1 shows the sub-microscopic representation of the juice particles drawn by the teacher on the board. Another visible component integrating with sub-microscopic representation is curricular whereby the group used the sub-microscopic representation to introduce the core concept: concentration.

> At home we say this juice is more sweeter than this one, but we have a name that we are going to call this juice. It is what we see there over the board, we talk of concentration. Now we are not gonna say that because this juice has 16 particles and this one has four particles that this juice is sweeter than this one (Pointing at the juice with 16 particles). We need to know how much concentration is found in these two juices.

This is an illustration of the teacher using the representation component to explain the important concept of the lesson. So, this episode shows integration of RP with LP; which are connected in a linear structure with sub-microscopic representation interwoven with what is WD and curricular saliency.

This lesson was taught by four pre-service teachers. The teachers were teaching about limiting reagents; a concept found in chemistry in stoichiometry topic. The group is named Mavis' group because she was the first person to introduce the lesson. They were all involved in the teaching of the lesson at some point. The extract below shows the introduction to the lesson. They started the lesson by conducting an experiment to teach about limiting reagents; as shown in the extract below. The rest of the lesson is explained Figure 5.2 below.

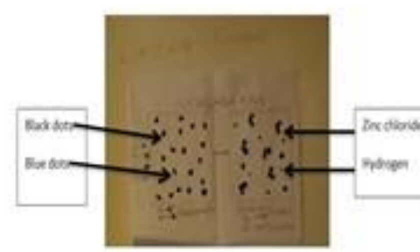
Teacher reacts zinc with hydrochloric acid and waits for a few minutes	Evidence of representation
Teacher: Now let us look at what was happening here. I think our reaction has stopped. This is our reaction. Now we are going to test which one is our limiting reagent and which one is our excessive reagent. Now I am going to put more zinc here (pointing at the reaction of zinc and hydrochloric acid). If Zinc reacts what does it mean in terms of limiting and excessive reagents? **Learner**: If it reacts it means that we still have both the reactants; it means that the hydrochloric acid is still there. **Teacher**: exactly, it means that the hydrochloric acid is still our excessive reagent. But what if it does not react? **Learner**: It means that now the hydrochloric acid is no longer a limiting reagent.	Evidence of learner prior knowledge (Finding out learners' prior knowledge on limiting reagents)
Teacher: Exactly. Now let us test our theory and see. By the way, what kind of a reaction is this? An endothermic or an exothermic? **Learner**: Exothermic. **Teacher**: Exactly, how do you know this is an exothermic reaction? **Learner**: something burns or something.	Evidence of learner prior knowledge (using pre-concepts of exothermic and endothermic reaction to find learners' preior knowledge)
Teacher: Exactly, heat was released in this reaction. Now I have my zinc and hydrochloric acid. Let's put this here (zinc in hydrochloric acid and zinc reaction) and see what is going happen with our zinc. It is quite difficult to see but.. **Learner**: There is no reaction **Teacher**: we can see that there is no reaction, as we remember at first we had smoke coming up, in this case there is none. This means that there is no reaction happening, even when we added zinc. So what does that mean? It means that our hydrochloric acid was? **Learner**: Used up.	Evidence of curricular saliency – concept of limiting reagent being explained in relation to a physical demonstration (macroscopic representation)
Teacher: Our zinc is the excessive reagent. Now let us look at the microscopic level what is happening in here. This is what is happening, before the reaction took place we had the black dots (pointing at the drawing), they represent zinc and then the blue and red dots they represent our hydrochloric acid. Now this is before a reaction can take place. We have this amount of zinc and this amount of hydrochloric acid so I made it easy for you, I have written it down. We have 9 zinc atoms; we have 12 hydrochloric acid atoms. **Teacher**: Now after the reaction we formed zinc chloride and this (pointing at the drawing of zinc chloride representation) represents zinc chloride. We are also going to form hydrogen, which was the gas that we saw ion the reaction, which is represented by two red dots over here. Now this is the zinc chloride that we have and this is the hydrogen represented in red dots. Now if we look in terms of this diagram, what can you say is the limiting reagent or is the excessive? **Learner**: There are more dots of hydrogen so it seems like... **Teacher**: There are more dots of hydrogen so if you have hydrogen in this case in here; if we have something in here (after reaction) which we do not have in here (before reaction) what does it mean? **Learner**: Sir can we say it's a left over? **Teacher**: The hydrogen? **Learner**: Yes	 Evidence of sub-microscopic representation integrated with conceptual teaching strategy and curricular saliency Platform: Conceptual teaching strategies 

Figure 5.2: Mavis' group's tsPCK Episode and a corresponding TSCK Map

In this lesson Mavis' group was teaching about limiting reagents. In this episode, the teacher started off by doing an experiment in order for learners to understand the concept of limiting and excess reagents, macroscopically. The representation was macroscopic, it was a reaction of zinc and hydrochloric acid. The students had to identify which substance was a limiting reagent between the two. The teacher then asked learners a question to find out if they knew about limiting reagents

> "Now let us look at what was happening here. I think our reaction has stopped. This is our reaction. Now we are going to test which one is our limiting reagent and which one is our excessive reagent. Now I am going to put more zinc here (pointing at the reaction of zinc and hydrochloric acid). If Zinc reacts what does it mean in terms of limiting and excessive reagents?"

This was another component coming up which is LP where the teacher was trying to find the knowledge of learners about limiting reagents using the knowledge they might have about the topic.

Another component that is also seen is the second learner prior knowledge where the teacher used an experiment to find out the learners' prior knowledge on exothermic and endothermic reactions, which was going to help the learners to know which substance is limiting the reaction.

> Teacher: Now let us test our theory and see. By the way, what kind of a reaction is this? Is it an endothermic or an exothermic?
>
> Learner: Exothermic.
>
> Teacher: Exactly, how do you know this is an exothermic reaction?
>
> Learner: something burns or something.

There is visible evidence of an interaction between LP and RP; where the teacher is using the experiment to find out about the learners' prior knowledge on exothermic and endothermic reaction. The teacher then used the experiment and learner's prior knowledge in order for learners to identify the limiting reagent. There was no smoke coming out of the test tube so the learners pointed that out and the teacher then told them that the reaction had stopped. From that representation, the teacher then told them that it meant that zinc was the excessive reagent because there was no more hydrochloric acid to prompt the zinc to react. The teacher was trying to explain the limiting reagent concept using representation and learner prior knowledge. That was evidence of another tsPCK component coming up which is curricular saliency (CS) whereby the concept of limiting reagent was explained in relation to a physical demonstration.

Another episode is spotted when the teacher took the macroscopic representation of the experiment and showed learners how it would look like when it is in sub-macroscopic representation by drawing it on the board; as shown in the Figure 5.2 above.

The sub-microscopic representation was a concept demonstrated by the teacher. The representation (RP) component was interwoven with the conceptual teaching strategy (CTS). The teacher used a strategy of drawing representations of HCl and hydrogen atoms with different colours. This showed learners how the other substance got finished after the reaction by drawing them in different shades; each molecule having a different colour. The teaching strategy made it easier for learners to count how many molecules of each substance they had before the reaction and how many molecules of the substance they had after the reaction. The teacher used the diagram to explain to learners the core concept of limiting reagents "Now this is the zinc chloride that we have and this is the hydrogen represented in red dots. Now if we look in terms of this diagram, what can you say is the limiting reagent or is the excessive?" The teacher used the macroscopic representation and critical teaching strategy to explain the most important concept in the lesson: limiting reagents. That is evidence of curricular saliency. The learner prior knowledge component is also integrated with the representation (RP) and the conceptual teaching strategy (CTS).

The observed interwoven nature of the TSPCK components is seen in this episode where representation (RP), Conceptual-teaching strategy (CTS) and Learner prior knowledge (LP) are integrated. So, in this lesson there are eight tsPCK concept that are all clustered together. Those concepts are representation (RP), learner prior knowledge (LP) interwoven with another learner prior knowledge (LP), representation (P), curricular saliency (CS), representation (RP), conceptual teaching strategy (CTS), and curricular saliency (CS). All these eight components formed a tsPCK map for Mavis' group's enacted actual teaching.

Themba's group had four members. They taught a lesson on stoichiometry under the concentration concept. In their lesson, they each took turns to teach, one person would introduce the lesson and the next would take over from the introduction while the other members would conduct an experiment. This extract came after the lesson was introduced whereby the introduction of the lesson started off with an experiment about concentration. As shown in the first sentence of the extract, they reminded the learners of the experiment that was done at the beginning of the lesson.

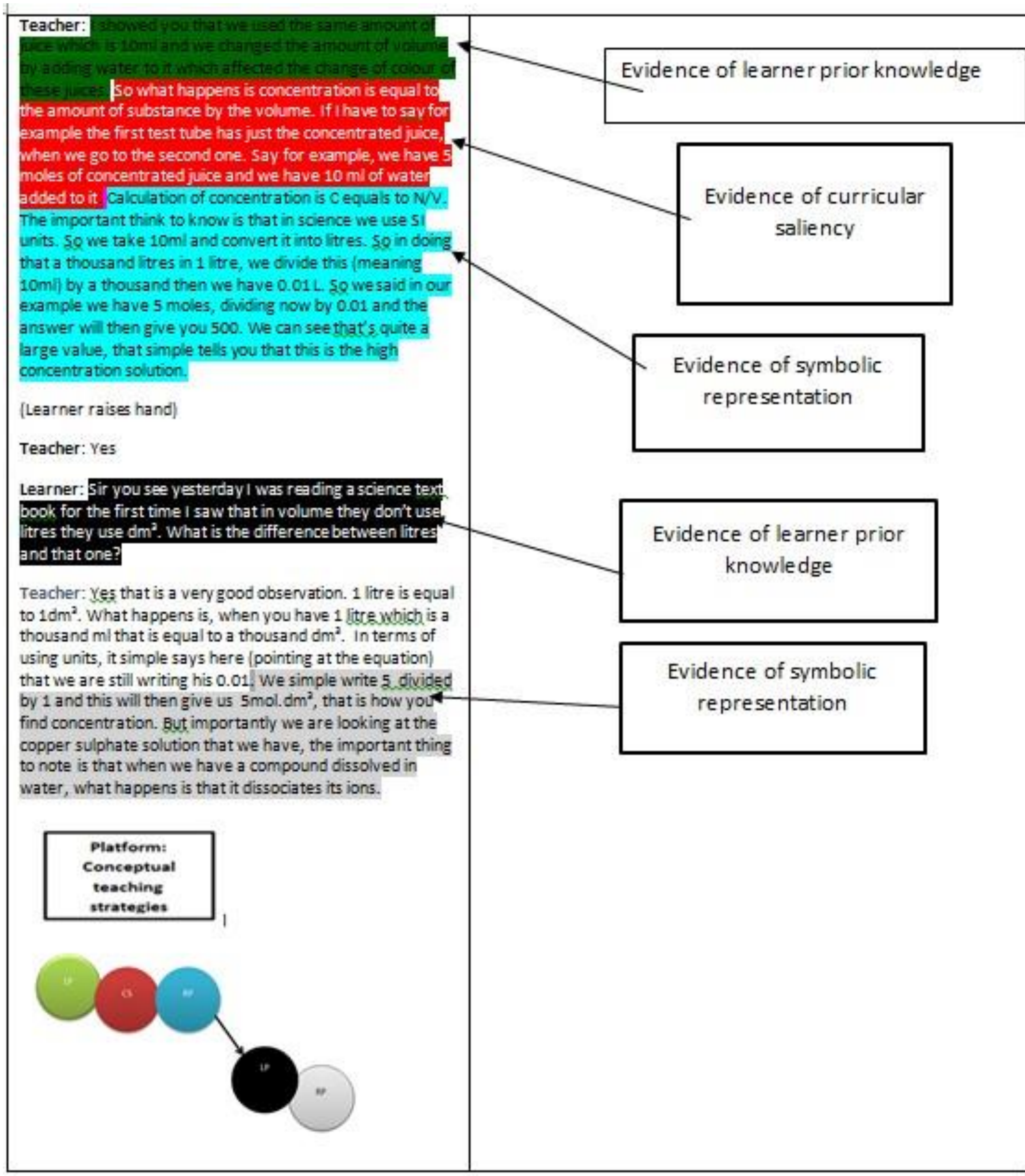


Figure 5.3: Themba's group tsPCK Episode and a corresponding TSCK Map

In this lesson Themba's group was teaching about the concentration concept in the stoichiometry topic. The teacher was teaching about the different kinds of substances with different concentration. She performed an experiment using different substances in order for learners to understand the concept of concentration.

Figure 5.3, above, shows that Themba's group started off their lesson by looking at the learner prior (LP) knowledge that they had done. The learners had finished doing an experiment with the teacher on how the concentration of a substance can be affected by diluting it. The teacher used that prior knowledge (about the experiment) to remind the learners of the experiment they did in order to connect it to what he was about to teach. Themba's group used learner prior knowledge in order to explain the curricular saliency. As seen, on Diagram 4.2.6, the group first reminded the learners about the experiment that they had done; "I showed you that we used the same amount of juice which is 10ml and we changed the amount of volume by adding water to it which affected the change of colour of these juices." That is evidence of learner prior knowledge. Fyfe, Rittle-Johnson and DeCaro (2012) argued that prior knowledge has typically been shown to facilitate learning and, decrease prediction errors during learning. The group used learners' prior knowledge in order to explain the core concept, which is concentration.

> So, what happens is concentration is equal to the amount of substance by the volume. If I have to say for example the first test tube has just the concentrated juice, when we go to the second one. Say for example, we have 5 moles of concentrated juice and we have 10 ml of water added to it.

While explaining concentration, a symbolic representation was used to elaborate more on the concept. The group gave the learners the formula used to calculate for concentration. To teach learners about the macroscopic phenomena, the symbolic level of representation is commonly used. It includes physical and computational forms such as chemical equations, and model kits (Treagust et al, 2010). The teacher used the symbolic representation in order for learners to understand how to figure out which substance is more concentrated than the other or how much concentrated a substance is. This signalled an interwoven interaction of three components: Learner prior knowledge (LP), curricular saliency (CS), and symbolic representation (RP).

While Themba's group was teaching learners on how to do calculations to find the amount of concentration in a substance, the teacher wrote a down a calculation and explained it to learners:

> The important thing to know is that in science we use SI units. So we take 10ml and convert it into litres. So in doing that a thousand litres in 1 litre, we divide this (meaning 10ml) by a thousand then we have 0.01 L.

A learner raised a question concerning this representation about the difference between litres and dm^3. “Sir you see yesterday I was reading a science text book for the first time I saw that in volume they don’t use litres they use dm^3. What is the difference between litres and that one?” That was a learner prior knowledge, which the teacher introduced. In order to explain it, the teacher used a symbolic representation (See Figure X) by showing calculations on how to convert ml into litres and that 1 litre is equal to $1dm^3$. That is evidence of learner prior knowledge elicited by the learner and the teacher used symbolic representation to answer the question. So, learner prior knowledge was interwoven with symbolic representation.

The pattern shown in Themba’s group’s teaching episode goes as follows: Learner Prior Knowledge (LP) is identified as the first component that is interwoven with Curricular Saliency (CS). These two components are linked with the symbolic representation (RP). The last interaction seen is the linear interaction of learner prior knowledge interacting with symbolic representation.

5.3 Summary

In summary, all the three enacted classroom teaching episodes have different quantities of tsPCK episodes which have different qualities. The quantities of tsPCK episodes seen in the groups is desirable. However, more emphasis is placed on the quality of the observed episode as an indicator of the teacher professional knowledge the pre-service teacher have. Exemplary tsPCK episodes provided insight on the nature of interactions of multiple components generated in a teacher task segment. The next Chapter analyses for tsPCK episodes in the implementation of the lesson plans analysed in this chapter, and looks for congruency with the generated plans.

CHAPTER 6

6. RELATIONSHIP BETWEEN ENACTED tsPCK in LESSON DELIVERY AND ACTUAL TEACHING

6.1 Introduction

This chapter delivers a response to a research question that looks at the relationship, if any, between the TSPCK in pre-service teachers' planning and in their classroom micro-teaching of stoichiometry. In this episode, this researcher compared and differentiated between the planning and the actual teaching of pre-service teachers. This researcher used the lesson plans of the participating groups and the microteaching videos to find out if there is any congruency between the two. This was achieved by looking at the TSPCK episodes of the lesson plans and microteaching videos of the three teachers. It allowed this researcher to identify the similarities and the differences between the two, if there were any. Such differences and similarities would be described by looking at the components that are shown: the quality of their episodes, the number of episodes for each lesson, and how the components interacted with each other. Table 1, below, provides an overview of the number of episodes which are there for the planning and actual teaching, and the quality of the episodes.

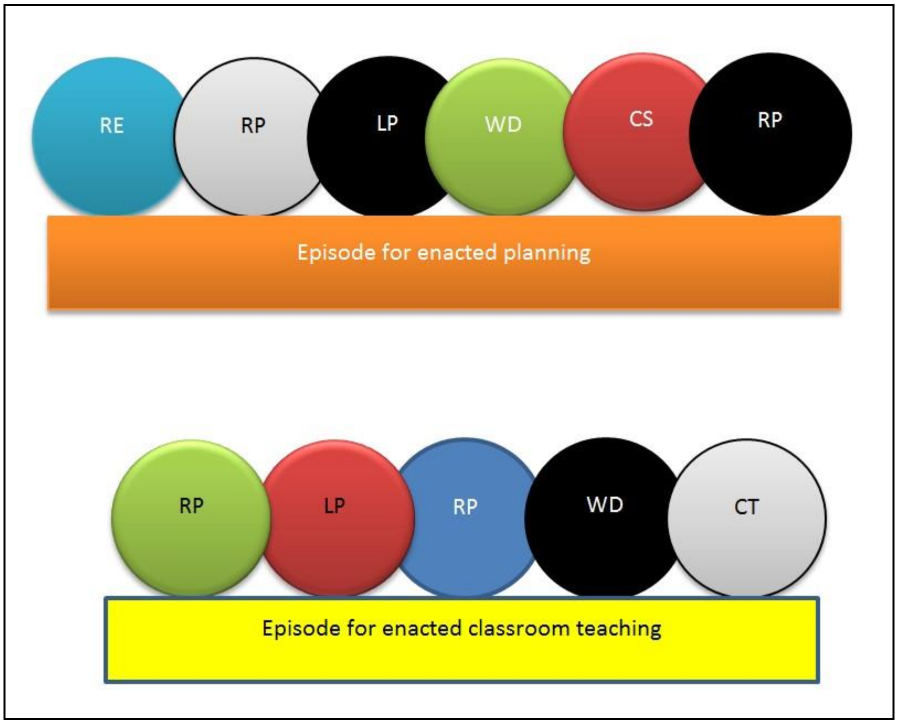


Figure 6.1: Andile's group's lesson plan and the enacted lesson plan with the tsPCK episodes

Andile's group planned and taught a lesson on concentration. Figure 6.1 above shows the two extracts of the enacted lesson plan and the enacted actual classroom teaching, together with their TSPCK episodes. An observation of the first components in the two extracts shows that they are both similar.

In Andile's group's lesson, there is macroscopic representation (RP) component interacting with learner prior knowledge (LP). In their lesson plan, Andile's group planned on giving learners a representation of two juices and asked the learners to identify which juice is more concentrated than the other. This means that they were using representation of juice in order to get learner's prior knowledge about concentration by questions given to learners about the concentration of the juice. In his actual teaching, Andile used the learner prior knowledge (LP) to correct any misconceptions that learners could have about concentration:

> I will assume that you put the juice that we were making, we take the small juice that we were making, and we add water (teacher adding water to the small portion of a substance). This is the juice that we are going to drink. What is there between the two juices?

In order to get that misconception, he used the macroscopic representation (RP) of the juice and then questioned the learners. This shows a congruency between the two first instances of planning and enactment.

After the learner prior knowledge component, Andile's planning moved to the *what is difficult to teach* component. Here Andile's group expected learners to find the concept of concentration difficult to understand. This is indicated by the group saying that after asking the learners questions about dilution and concentration "one of the expected answers from the learners is the weakness and how strong the other juice is compared to the other, which is *concentration*". That concept of what is difficult to teach (WD) was interwoven with curricular saliency (CS) whereby Andile's group said that they will use the learners' answers to explain thoroughly what concentration and dilution is.

In their enacted lesson, after the learner prior knowledge component, Andile's group used sub-microscopic representation to explain the concept of concentration. That is when they introduced another component which is *what is difficult to teach* (WD). The component *what is difficult to teach* (WD) was triggered by the learner who asked: "but sir how do we know which one (juice) is sweeter?" In his teaching Andile used the macroscopic representation of diluted juices to help students understand the macroscopic concept of concentration in a microscopic way because it is very difficult for people to explain things that they cannot see, such as taste, colour or extent of sweetness and link them to concentration. The WD component then interacted with curricular saliency when they started to teach about concentration.

The difference between the enacted lesson planning of Andile's group and their enacted classroom teaching is not vast. Even though the arrangements of the components are not similar, the components in enacted planning also appear in enacted classroom teaching.

	Limited(1)	(2) Basic	(3) Developing	Exemplary (4)
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

Figure 6.2: An enacted lesson plan rubric

Type 1: **Basic TSPCK Episodes**	**Type 2:** **Proficient/Developing Episodes**	**Type 3:** **Sophisticated/exemplary Episodes**
• These are simple 2-component TSPCK Episodes. • The two components interacting are clearly, explicitly distinguishable • Both components work together to support an explanation of a single or a pair of concepts that are related	• These are 3- component TSPCK Episodes. • The three components interacting are clearly, explicitly distinguishable all being used at a single/one dimension level e.g. if it is representation sit will be only macro or symbolic or submicro. Or • That one of the three components is a component that is addressed implicitly based on the choice of representations or explanations • The three components work together to support an explanation of a single concept	• These are 4- component TSPCK Episodes with one of the components might or might not be repeated in the teaching segment or • The three components interact clearly, explicitly and are distinguishable, the repeated component is also distinguishable • The four components interacting are clearly, explicitly distinguishable • All four components work together to support an explanation of a concept • Three components evidently interacting and one being used at different representations all three being present

Figure 6.3: An enacted actual classroom-teaching rubric

An observation of the two rubrics shows that both the enacted lesson plan and the enacted actual classroom teaching their qualities are exemplary. That is because, according to the lesson plan rubric in Figure 2 (Check Appendix 1), when a lesson is exemplary there is a consideration of student prior knowledge and/or misconceptions, evidence of at least one aspect related to curricular saliency, and it uses at least two different levels of representations to facilitate understanding. That is what Andile showed in his planning. The TSPCK map supports that there is a consideration of student prior knowledge and evidence of confrontation of misconceptions, the lesson plan also considers curricular saliency and uses either macroscopic or symbolic representation. Andile's group's planning shows all the components mentioned in the exemplary stage. They first confronted the student prior knowledge by using a representation of juice to ask them questions on concentration in order to find learners' knowledge or misconception about concentration. There is also a consideration of curricular saliency when Andile's group said that they will use the answers of learners to explain thoroughly what concentration and dilution is. They also used macroscopic and sub-microscopic in their planning whereby the macroscopic representation was the juice that was used at the beginning of the lesson and the sub-microscopic was the growing of the particles of the juice. This proves that Andile's group's lesson planning was exemplary and the tsPCK map shows that.

Andile's group's enacted lesson was also exemplary. According to the rubric, the enacted lesson is exemplary if there are 4- component TSPCK episodes with one of the components that might or might not be repeated in the teaching segment and all the four components work together to support an explanation of a concept. Their lesson considered a confrontation of the learners' misconceptions (LP) and using a macroscopic representation (RP). Andile started his lesson by doing a practical exercise about concentration. Using that practical exercise, he confronted learners' misconceptions by asking which juice will be more concentrated than the other. The teacher then explained the macroscopic representation in a sub-macroscopic representation (RP) so that the learners could see how the particles would be arranged for diluted and concentrated substances. By using that sub-macroscopic representations, he was trying to help learners comprehend what they found difficult to understand (WD) about the microscopic part of concentration because it is difficult to explain to people things that they cannot see, such as taste, colour or extent of sweetness and link them to concentration. So, there are four components seen in the lesson and they work together to support the explanation of the concentration concept. Therefore, the enacted lesson was exemplary.

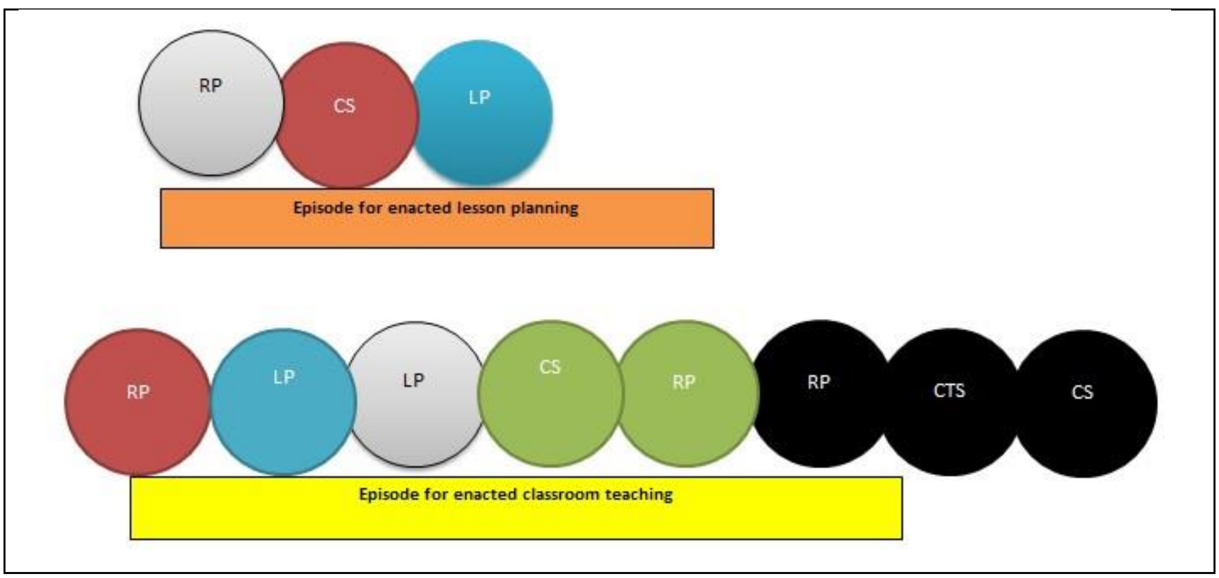


Figure 6.4: Mavis' group's lesson plan and the enacted lesson plan with the tsPCK episodes

Mavis' group planned and taught his lesson on limiting reagents, which is a topic in stoichiometry. Figure 6.4 shows her TSPCK episodes with extracts the lesson plan and her enacted lesson. In her lesson plan, there is one episode, as shown in Figure 6.4 above. Her enacted classroom teaching also has one episode. Their enacted planning and enacted classroom teaching are very different.

The enacted planning has only three components while enacted classroom teaching has eight tsPCK components. In their planning, they said that they will start their lesson with an experiment on limiting reagent whereby two reactants will react and the other one will get consumed first in order to show that the consumed product is the limiting reagent. That shows between representation and curricular saliency where curricular saliency is when they put emphasis on the core topic that they planned to teach. In their teaching, they also started with a representation. They performed an experiment in order for learners to understand the concept of limiting and excess reagents macroscopically. The representation was macroscopic, it was a reaction of zinc and hydrochloric acid whereby the students had to identify which substance was a limiting reagent between the two. That is the congruency seen between the planning and the actual teaching whereby she planned on starting off with an experiment and in the actual lesson she started off with an experiment.

In her first episode, there is evidence of interaction between representation component and curricular saliency (CS). This is shown where she said that after the experiment she will teach learners about limiting reagents and then ended with symbolic representation whereby they planned on teaching learners how to calculate for concentration. The three components are interwoven as demonstrated Figure 6.3. The actual classroom teaching, however, differs because after the macroscopic representation, the teacher introduced learner prior knowledge by asking questions on limiting reagents regarding the substance they thought would stop the reaction. They then moved on to another learner prior knowledge which was about the topic that they had learnt before; whereby they had to use the exothermic and endothermic reaction knowledge to tell which substance would be a limiting reagent. The group had not planned that far. However, they moved on into teaching about the core concept which involves explaining the concept of curricular saliency using the experiment they did; which was an interaction of representation and curricular saliency. They ended up by using a sub-microscopic representation to explain more about limiting reagents. They also used a teaching strategy of drawing dots of different colours to show which substance was limiting the reaction and which one was in excess. That showed three more tsPCK components interacting: representation (RP), conceptual teaching strategy (CTS), and curricular saliency.

The quality of the lesson plan and the enacted lesson is different. According to their rubrics, the enacted lesson plan is developing and the enacted lesson is exemplary. According to the rubric, when a lesson plan is developing it means that there are three components of tsPCK episodes in it and the components should be clearly used as a single dimension and they should support a single concept. The tsPCK episode in Mavis' group's teaching shows three components interacting to explain a concept of limiting reagents.

The enacted lesson, however, is exemplary. The lesson had one episode that had eight components that were interwoven. One component was used to move to another component in a sequential manner. The first episode was macroscopic representation which was an experiment that Mavis' group did with learners, she used that representation to ask learners about limiting reagents which was going to help Mavis to find out learners' misconceptions. The answers that learners gave led the teacher to ask about the prior topic on exothermic and endothermic reaction to help learners understand how to find a limiting reagent. The answers that the learners gave lead the teacher into explaining the concept of limiting reagents using experiment; showing an interaction of representation and curricular saliency. The group then ended their lesson by using sub-microscopic representation and conceptual teaching strategy to explain the concept of limiting reagent.

There is a huge difference between Mavis' group's enacted planning and enacted classroom teaching. Even though the enacted planning was developing and the enacted classroom teaching was exemplary, there is still a huge gap between the two. The enacted planning only had three (3) tsPCK components and the enacted classroom teaching has eight (8) tsPCk components. Therefore, there is little to none congruency between the enacted planning and enacted classroom teaching of Mavis' group.

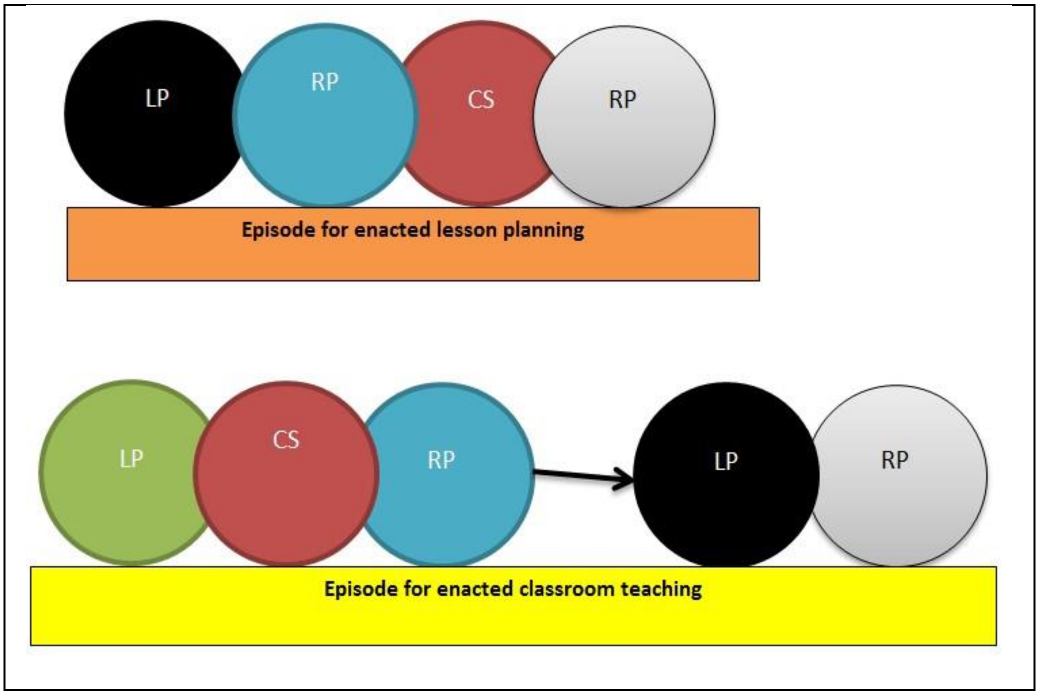


Figure 6.5: Themba's group's lesson plan and the enacted lesson plan with the tsPCK episodes

Themba's group planned and taught about the concentration concept in the stoichiometry topic. The lesson plan and the enacted lesson are not matching. Both the enacted lesson plan and the enacted classroom teaching have one episode. The episode shows a linear pattern of two components: learner prior knowledge (LP) and curricular saliency (CS). It also shows an integration of two components: curricular saliency (CS) and representation (RP). There is a connection of the last component with the first component which is representation and learner prior knowledge (LP) as shown in Figure 6, above. In the enacted lesson there is also one episode. The enacted lesson shows learner prior knowledge (LP) as the first component interwoven with that of representation (RP), curricular saliency (CS), and macroscopic representation (RP), these 4 components are linked symbolic representation (RP) and learner prior knowledge in a linear form.

Themba's group planned to start with recapping on Avogadro's number and asking learners about it; which is learner prior knowledge, it interacted with representation where they planned to use macroscopic representation to explain the concentration concept. This was an interaction of macroscopic representation and curricular saliency. They then said that they will end their lesson with teaching learners how to calculate for concentration, which is symbolic representation.

Themba's group planned to start his lesson by recapping on the previous lesson about Avogadro's number and calculation for the number of moles and then moved to say that they will give learners an experiment on concentration. That shows an interaction of learner prior knowledge and representation. In their enacted lesson they started their lesson by finding learners' prior knowledge on concentration where they used a representation of different substances with different concentration. Even though they planned to start with finding learner's prior knowledge and in their enacted classroom teaching they did start with learners' prior knowledge; which is linked with curricular saliency where there is an emphasis of the explanation of concentration. The curricular saliency is interwoven with the symbolic representation whereby the group used the formula of calculating for concentration to teach learners how to get the amount of concentration. A learner's question had a great impact of the difference between the enacted planning and the enacted classroom teaching of Themba's group. The learner asked a question regarding the introduced symbolic representation where he did not understand how the teacher came up with the SI units for volume. The teacher had to use the symbolic representation to correct the learner's misconception. That is where the two components came up: learner prior knowledge and symbolic representation. The enacted lesson planning and the enacted classroom teaching are both exemplary; however, the enacted classroom teaching has more tsPCK components than the enacted lesson plan.

CHAPTER [1]

7 CONCLUSION

7.1 Introduction

This research is set out to answer two research questions, namely:

1. What is the quality of TSPCK evident in the pre-service teachers' planning for teaching stoichiometry?

2. What is the quality of TSPCK evident in a teaching setting of stoichiometry by pre-service teachers?

3. What is the relationship, if any, between the quality of TSPCK in pre-service teachers' planning and classroom teaching of stoichiometry?

The research study was based on the construct of TSPCK developed by Mavhunga (2012). It was performed on three fourth year pre-service teachers doing a physical science methodology course. The research used an in-depth qualitative method to analyse the results. Examples of lesson plans and enacted lesson extracts by participants were used to explain some of the findings in a qualitative manner, using the lesson plan and enacted lesson rubric. The University of Witwatersrand granted the ethical clearance to carry out this study. The research tools that were used to collect data were the lesson plans, the enacted lesson videos of pre-service teachers doing microteaching, and the pre-service teachers' report about their teaching and planning. The quality of the lesson plans and enacted lessons were validated using two rubrics by Mavhunga and Rollnick (2013) and Miheso and Mavhunga (2017). Two assistants helped to score the lesson plans and enacted lesson quality for reliability of scores. The lesson plans and enacted lesson were also analysed qualitatively to illuminate the statistical data. The results indicated that two lesson plans had episodes that were exemplary and one only had basic episodes.

As shown in the overview analysis of the individual participant findings on Table 1, the first group (Andile's group) had three TSPCK episodes in his planning. The quality of the first episode was exemplary and two episodes were basic. The first episode was interwoven with six components, the second episode was basic with only two components while the third episode was interwoven with two components and was also basic. All of Andile's group's three episodes had the representation and learner prior knowledge components. Mavis's lesson plan had one episode which had three components each. The quality of the episode was *developing*. The last participant, Themba's group's lesson plan had one exemplary enacted lesson plan which had four tsPCK component with two that interacted linearly and the three that were interwoven. All the lessons had the representation and prior knowledge tsPCK components. This means that when the teachers prepared for the lesson they considered the knowledge of the learners. They also found a better way of explaining the topic using a representation in order for learners to understand the component taught better.

Research Question 2 looked at the quality of TSPCK evident in a teaching setting of stoichiometry by pre-service teachers. To answer Question 2, the results indicated that all the enacted lessons had at least one exemplary episode. Most of the episodes were interwoven and had more than three TSPCK episodes each. Andile's group's enacted lesson had three episodes with two *basic* and one *exemplary*. The first episode's quality, according to the rubric, was *exemplary*, the second episode was *exemplary* and the third episode was *basic*. All of the episodes were interwoven in nature whereby the first episode had five interwoven tsPCK components, the second episode had four components that were all interwoven. The third episode had two interwoven components. Mavis' group's enacted lesson had one episode. Its quality is exemplary and has eight tsPCK components all interwoven. Themba's enacted classroom teaching had one episode with five tsPCK components. Three of the components were interwoven and linearly connected to two components. Most of the episodes in the enacted lessons are interwoven, this might mean that when the teachers were teaching they managed to connect one component to another in order to make the lesson more understandable and they had more to say due to classroom interaction and learner questioning.

Research Question 3 focused on the relationship, if any, between the quality of TSPCK in pre-service teachers' planning and classroom teaching of stoichiometry. The enacted lesson plans and the enacted classroom teaching were not entirely congruent. Even though there was a relationship in terms of components in the lesson plans and enacted lesson, the enacted lessons had a better quality than the lesson plans. Most of the enacted lessons were interwoven and had more components than the lesson plans. For example, Themba's group's lesson plan has four tsPCK components whereby the last component was learner prior knowledge interacting with representation. This enacted lesson plan has five components where the last component in the first four components is also representation. The two additional components were triggered by the learner questioning where the teacher had to use representation to help the learner with their prior knowledge. This shows that the group had not planned or prepared for the question that the learner asked. However, because they had to address that question they had to find ways to explain what the learner asked. That was spontaneous and unplanned and caused the difference between the lesson plan and the enacted lesson. Some of the clusters in the enacted lesson spoke directly to the planning that took place. Nonetheless, most of the clusters were less in the lesson plan than the enacted classroom teaching. The enacted lesson, therefore, was broader than the planning. Ling and Marton (2011, Pp 9-10) supported the results that lesson planning is not always in congruency with enacted learning by saying that "the intended object of learning planned by the teacher may not be the same as the enacted object of learning as the teacher tried to implement a lesson plan amidst the complex and dynamic nature of classroom interactions." This could be the reason why what the teacher plans and what they actually enact may not be the same. This is what this researcher is interested in for this project.

7.2 Generalizability limitations of results and recommendations

This study showed that planning is not always congruent with the actual teaching. However even though the two are not always totally matching, the intentions in the lesson plans are seen in the actual teaching. Some of the intentions in the lesson plan are scattered or interacting in a linear way and when they come out in enacted lesson they are clustered and interwoven. This study showed that planning a lesson does not mean that it will always come out exactly as it is in the enacted lesson. This in in keeping with the views of Ling and Marton (2011) who say: "The intended lesson plan may not be the same as the enacted lesson due complex and dynamic nature of classroom interactions". Sometimes the lesson can be disturbed by the way the learners are interacting with the teacher, learners may not respond to the teacher or they may be noisy and playful in a way that teacher may not teach what they intended to teach when they planned the lesson. The study indicated however that it is always important to plan for the lesson because it helps to provide direction on how to teach and to prepare for the lesson better such as having the right experiment to help learners understand a certain topic better. The department of Education can adopt this method of lesson planning and help the teachers to effectively plan for the lesson and making sure that they are well trained to prepare for the fact that the enacted lesson may not go exactly as planned in the lesson plan; even though the lesson plan is still crucial for teaching.

There were limitations to this study. The challenging part of this study is that some of the lesson plans were short; especially on the teaching strategies. This made it hard to analyse the lesson. The reason for the short lesson plans could be that the teachers found the lesson planning process more tiring or difficult than the actual teaching or it might have been that they did not have enough time to plan. The other limitation is that this was micro-teaching; done with their fellow classmate. So, the results might not have been properly captured as they would have been in a real classroom situation. That is because the fellow classmates already knew the stoichiometry topic so they understood the teacher easily.

7.4 Reflections

This study showed that it is essential to plan for lessons as that would aid the teacher with the right direction in actual teaching. It also showed that the lesson plan will not always be in congruency with the enacted lesson as there will always be changes that need to be made during the lesson due to different factors such as questions from the learners, equipment not working properly, or the teacher spending time trying to manage learner behaviour. If the government could implement thorough planning of the lessons and teachers learn to implement it then this researcher believes teachers would be equipped with more and better knowledge on how to teach science. Using qualitative in-depth method was useful because it gave this researcher rich data, which assisted rechecking the data whenever a gap was observed in analyses and reporting. With the nature of this in-depth qualitative analysis, the researcher was able to describe the complexity of enacted tsPCK in planning and in practice. This researcher also observed that pre-service teachers did not provide adequate information in their lesson plans. Hence, one of the groups was skipped. There were visual problems encountered while watching to transcribe and capture the pre-service teachers' board work. Some of the work written on the board were not legible. In that case, the researcher made efforts to connect what the pre-service teachers were saying to make sense of their legible board work.

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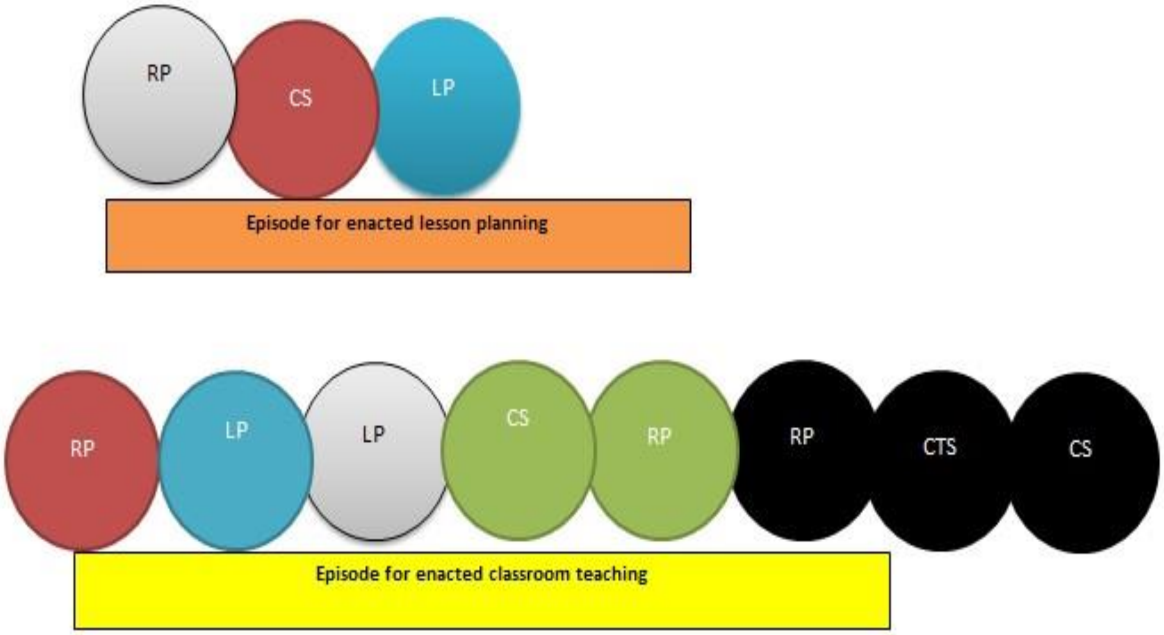
Appendixes

Appendix 1: Rubric for enacted actual classroom teaching.

	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 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 include conceptual scaffolding with reference to other TSPCK components
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.
Representat-ions	• 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

	Limited(1)	(2) Basic	(3) Developing	Exemplary (4)
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

Appendix 2: Rubric for lesson plans



Appendix 3: Student teachers' lesson plans

Andile's group's lesson plan Lesson plan

Subject	Physical sciences
Grade	11
Topic covered	Mole
Specific concept	Concentration
Allocated time	45 minutes

Category A: Aspects related to curricular saliency

1. Purpose:
    - Aim of the lesson is to teach learners about concentration, show them how it links to mole concept.
    - Teach them the calculations of concentration.
2. The concept of amount of a substance is a prerequisite of concentration, because concentration is about the amount of a substance per unit volume so learners firstly need to grasp the amount of substance so that they can be able to understand when we talk of it in relation to it. The next concept is the mass because learners need to change substance given in mass to amount of substance which also means they should also know the molar mass in relation to periodic table (working with empirical formula).
3. Solution is a homogeneous mixture composed of two or more substances. In such a mixture, a solute is a substance dissolved in another substance, known as a solvent. The solution more or less takes on the characteristics of the solvent including its phase. A solute in a given solution has concentration, which is the property of solutions. Where we look at the amount of a substance per unit volume ($C=n/v$). Dilution is the process of decreasing the concentration of a solution by addition of a solvent to a substance.

    Category B: about learner prior knowledge

4. Misconception:
    - Most learners have the misconception that if a solution has equal volume it has the same concentration, or think that if we have different volume we have

different concentration. Learners fail to not that concentration is influenced by the amount of a substance in the volume.

- Another misconception which learners have is that when we create a solution out of two different solutes but with the same mass it will have the same concentration. This misconception is influenced by the misconception of amount of substances in given mass.

Category C: aspects difficult to understand

5. A learning difficulty which learners have it that when we add a substance of the same concentration in one container the concentration will then change since the volume increases when we add. It is difficult for learners to shift from focusing on concentration as the solely linked to volume of the solution or as volume being only affected but looking at the volume in terms of it bring the same property of the solution.

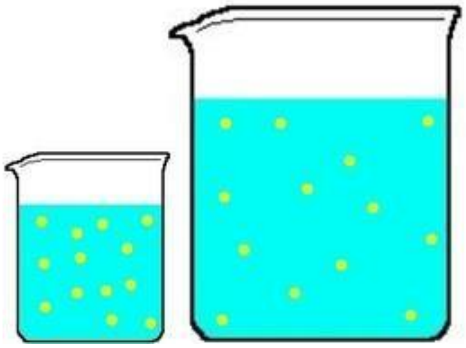
Category D: use of representation

Macroscopic

- Demonstration of different concentrated solutions; this will allow learners to observe macroscopically the idea of concentration using their visual aids. Learners will look at the colour changes, different masses and all observable aspects that can help them understand the concept of concentration. The chosen demonstrations will rectify the above mentioned learners misconceptions.

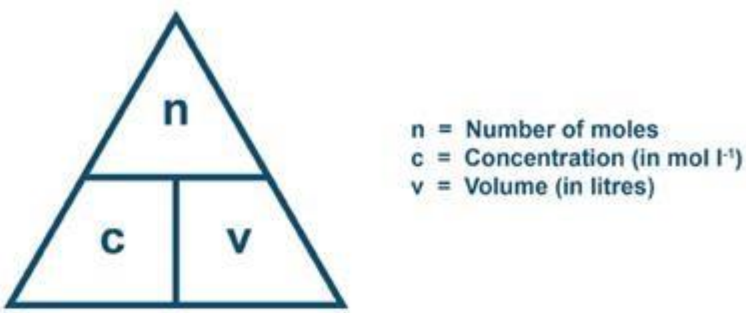
Sub –microscopic

- Pictures that show molecules- this is also a visual aid, it will help learners to make the relationship between macroscopic and sub-microscopic concepts. Working with the definition of concentration "***concentration*** is the amount of solute per volume of solvent". This representation will help learners to understand the definition of the concept of concentration.



Symbolic

- The use of the formula to calculate concentration. Learners will use the formula: C=n/v to calculate concentration, this will help learners to understand that they can always calculate the concentration of a substance if they know the amount of that substance and the volume of the solvent they will use, leaners can be used this representation and formula to calculate concentration even in their everyday lives.



Category E: Sequence and conceptual teaching strategies

Aim of lesson step with minutes	**Description of what will happen**		**Resources**
	What the teacher will do	*What the learners will do*	
To introduce the lesson *(5 min)*	The teacher will bring a glass half-filled with a juice, show it to the learners, and ask them to imagine the juice with 10 particles in it, and then add water to it. At this point, the teacher	The learners will observe what the teacher will be doing and follow the	- Water - Juice - Glass

	will ask the learners to draw the number of particles that will be present in the juice after adding water and how they will be positioned.	instruction (which will be to draw the glass of juice with water, showing the particles inside)	
To explain a concept *(10 min)*	Continuing from the previous lesson step, the teacher will collect answers from the learners on what they understood from the activity. One of the expected answers from the learners is the weakness and how strong the other juice is compared to the other, which is *concentration*. The teacher will use this answer as a point of departure from which he is going to explain the concept of concentration thoroughly. In his explanation the teacher will use sub-microscopic representations to put more visually what the learners had already seen with the juicy activity. Now, representing that symbolically, the teacher will give the learners the equation used to determine concentration, which is $c = n/v$.	The learners will raise hands and give answers to the teacher when pointed. After that, they will listen attentively to the teacher, and jot down some notes.	➢ White board ➢ Marker ➢ PowerPoint slide
To demonstrate the concept *(20 min)*	Now to explain concentration in a macroscopic representation, we will use the same amount of a substance in the same volume, then with different amounts but same volume and lastly with different amount and different volume (using food colouring). In the demonstration there will be moments where learners are asked to predict the outcomes before they observe the correct answer in the demonstration. Explanation will be given per demonstration.	Learners will be asked to participate in explaining if concentration is same or different.	➢ Beaker ➢ Test tube ➢ Food colouring ➢ Measuring cylinder

Calculation and practice questions *(10 min)*	We will apply the theory in using symbolic representations, where we do calculations which related or prove what we are talking about in representations. The calculations will be linking their prior knowledge about the mole because we will be working with the measured mass of the two chemical used in the demonstration.	Learners will observe my first practice and then they will then do other examples on their own.	➢ Board
Recap *(5 min)*	Ask important sub-concept which will make up the big idea of concentration, ask learners to refer to the representations in their response	Effective response to the questions possessed	N/A

Category F: assessment

Homework will be given from their school text book

Mavis' group's lesson plan

Subject	Physical sciences
Grade	10
Topic covered	Stoichiometry
Specific concept	Limiting reagents
Allocated time	45 min

Category A: ASPECTS RELATED TO CURRICULUM SALIENCY PURPOSE:

- During the lesson, the learners will observe a chemical reaction in order for them to visualize the concept of limiting reagent, and allow them to discover the concept dealt with.
- During a chemical l reaction the amount of reactants present at the beginning of the reaction determine the amount of reaction present at the beginning of the reaction to determine the amount of product formed, hence learners will know that the reactant that is completely used up in a reaction is called a limiting reagent, and the reactant that is left over after a chemical reaction is in excess.
- During the lesson, learners will be able to identify the limiting reagent in chemical reaction, based on the observed experiment.
- During the lesson, learners will learn how to use co-efficient to represent the stoichiometrically equivalent molar ratios that can be used to determine the amounts of reactants and yields of products
- At the end of the lesson, learners will be able to should know that a balanced chemical equation provide the combining ratios of reacting substances and the products formed. They will be able to solve stoichiometric problems with limiting reagents using balanced chemical equations.
- At the end of the lesson, learners will know that the amount of product formed during chemical reaction is determined by limiting reagent.

The most immediate concepts need prior to teaching the concept of limiting reagent are the concept of amount of substances, the molar ratios, the relative mass relations, concentration, balancing chemical equations, and conservation of mass.

SUMMARY OF THE MOST IMPORTANT CONTENT KNOWLEDGE

Limiting reagent is a substance that is used up first in a chemical reaction, and the substance left is in excess. During a chemical l reaction the amount of reactants present at the beginning of the reaction determine the amount of reaction present at the beginning of the reaction to determine the amount of product formed. The limiting reagent limit the amount of product formed. The mass and the amount of substance are used to calculate the product formed. The ratio of the co-efficient in a chemical reaction is used along with the moles to determine the limiting reagent and the reactant in excess.

Stoichiometric calculations with the limiting reagent:

- Find the amount of each of substance
- Examine the ratio of amounts of reactants
- Calculate the mass of product
- Calculate the mass of excess reactant

  Use the mass to calculate the amount of the amount of substances of the products, the n compare the two and identify the limiting reagent and the reagent in excess.

Introduction

Dance analogy

Introducing a concept

Perform a demonstration using one reactant becomes entirely consumed and the other reactant is left over. The reactant that becomes consumed is called the limiting reagent. When the limiting reagent is all consumed, no more products can be formed (reaction complete). The reactant limits the amount of product that can be formed. In the sandwich analogy above the bread, cheese and ham are not just analogies for the reactants; they also represent the number of moles or particles available for reaction. As soon as one reactant is consumed, the reaction stops because there are no longer particles of that reactant available for reaction. The reaction is limited by the availability of this reagent.

In this experiment, you will predict and observe a limiting reactant during the copper (II) chloride oxidation. You will use the single displacement reaction of aluminum with aqueous copper (II) chloride. $2Al(s) + 3CuCl_2(aq) \square 3Cu(s) + 2AlCl_3(aq)$

Copper (II) chloride, $CuCl_2$, turns a light blue in aqueous solution. This is due to the $Cu^{2+}(aq)$ ion. Aluminum chloride is colorless in aqueous solution.

Copper is mankind's oldest metals, dating back more than 10,000 years. The copper (II) chloride oxidation reaction has been used in petroleum industries for sweetening (a refining process used to remove sulfurous gases from natural gas). This process has also been used for etch regeneration, in which $CuCl_2$ is used to remove unwanted copper from printed wiring boards and discrete areas are etched away.

At the end, the teacher and the learners will calculate the limiting reagent in the chemical reaction they have performed. The teacher will show more than one method of finding the limiting reagent in calculations, thus using the symbolic level of representation to engage with the learners.

Themba's group's lesson plan

Grade 11

Theme: Chemical change

Duration: 1 hour 20 minutes

Subtopic: Molar volume of gases and concentration of solutions

Subtopic of the lesson that came before: Revision of grade 10 Stoichiometry

Purpose of the lesson

- Learners should know that 1 mol of gas occupies $22.4dm^3$ at 0^0c (273k) in one atmosphere (101.3KPa) (STP)
- Learners should be able to interpret reactions equations- volume relationships for gases under same conditions of temperature and pressure
- Learners should be able to calculate molar volume of gases
- Learners should be able to calculate molar concentration of solutions

Skills

At the end of the lesson:

- Learners should be able to tell how many volumes are there for a given molecule by looking at the molecules of an equation.
- Learners should be able to calculate the volume of a given molecule because they should know that one mol of gas occupies $22.4dm^{3.}$
- Learners should be able to change the subject of an equation to calculate an unknown e.g. C= n/V and V=n/C

Summary of content knowledge.

Many reactions involve gases. Weighing solids and liquids is relatively simple, but weighing a gas is difficult. It is much easier to measure the volume of a gas but we first need to relate the volume of gas to the number of atoms or molecules present- that is, the number of the gas. Avogadro's law says that equal volums of all gases (at the same pressure and temperature) contain the same number of units (atoms or molecules) This means that when two gases react with each other, their reacting volumes have simple ration to each other and to the product (if t is also gas). At the same temperature and pressure, the volumes of gases are directly propotional to the number of the gases present, because pV= nRT. Experiments have shown that at STP (standard Temperature and Pressure), one mole of gas occupies a volume of 22.4 dm^3 or 22.4 litres. This is called the molar volume of a gas.

The concentration of a solution is the amount of the solute present in a given quantity of solvent. If a large amount of a solute is dissolved in a small amount of solvent, a concentrated solution is made. If a small amount of solute is dissolved in a large volume of solvent, a dilute solution is made. The concentration of a solution can be expressed in many different ways. Molarity (M) or molar concentration is the number of moles of solute in 1 litre (1 dm^3) of solution. To calculate the concentration of a solution, we use Concentration = mole/volume which is c=n/v. Combining this equation and the equation for mole n=m/M we now have C= m/MV and m= cVM. Where concentration © is measure in mol.dm^3, Moles (n) is measure in mole, Volume (V) is measure in mol.dm^3, mass (m) is measure in g and molar mass (M) is measured in g. mol^{-1}.

Thinking about learners' needs

Learners are familiar with Avogadro's number, so when the Avogadro's law is being mentioned to them they will be able to relate easily to what is being taught. Other learners would still have a problem with balancing the equations which is important in this topic, so the balancing of an equation will have to be touched a bit during the lesson.

Common misunderstandings

Some learners might find it hard to understand Avogadro's law and how it is applied or they may think it does not make much sense to say moles and volume are proportional. Other learners might try to calculate volumes with an unbalanced equation which will obviously give them the wrong answer.

Pre-empting the misunderstandings

Emphasis on the law of Avogadro has to be made and learners will have to get lots of examples so that they may understand how the calculations are made.

Teaching strategies.

The first thing that will be done is to recap on the previous lesson bout Avogadro's number and calculation of number of moles. From there learners will be introduced to a new topic. The concepts will be explained to them while asking them questions during explanation. Learners will be given examples of calculations and at the same time asked to calculate too. An experiment of concentration will be done for the learners in order to understand the term concentrated and dilute. After the experiment they will be asked questions and then given an equation of calculating concentration which will be more likely a reminder because they did it last year. They will then be given a class activity to complete.

Sequence of the lesson steps that build a process of learning

Aim of the lesson step	Detailed description of what will happen in each lesson step	Resources needed
Baseline	Recap of the previous lesson	
Explaining a concept	The concept of molar volume of gases will be explained to learners with examples given to them.	
To demonstrate an experiment	An experiment showing what concentration really means will be demonstrated to learners	Coffee, sugar, water, beakers and a stirring rod.
Recap	The concepts and equations will be revisited and learners will be asked questions according to the lesson that was presented.	
Complete a learning activity	Answering questions	Learners' books and hand outs

Class activity

1. Write down Avogadro's law.
2. 5.10g of pure silver is dissolved in $250cm^3$ of water. Calculate the concentration of the solution.
3. What is the volume of 2 mol hydrogen gas at STP?
4. Calculate the mass of MgO needed to neutralize 40,0 ml of $0.25mol.dm^{-3}$ HCL solution.
5. $70,0cm^3$ of a sodium hydroxide solution (concentration = $0.180\ mol.dm^{-3}$) reacts completely with $30.0cm^{-3}$ of a sulfuric acid solution. a. Write a balanced equation for the reaction.
   b. Calculate the concentration of the sulfuric acid solution.
   c. Calculate the mass of the sodium hydroxide used in the titration.

Appendix 4: Ethics approval

Wits School of Education

WITS UNIVERSITY

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13 October 2017

Student Number: 683962

Protocol Number: 2017ECE050M

Dear Mpumelelo Faith Zondi

Application for Ethics Clearance: Master of Education

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

Exploring the relationship between the pre-service teachers' quality of TSPCK acquired in planning and that enacted in their classroom practice.

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

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

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

All the best with your research project.

Yours sincerely,

Wits School of Education

011 717-3416

cc Supervisor - Prof Elizabeth Mavhunga and Prof Marissa Rollnick