Examining pre-service teachers' reflections on their classroom teaching in order to identify Topic Specific Pedagogical Content Knowledge in their practice.

A research report submitted to the Faculty of Science, School of Education, University of the Witwatersrand, Johannesburg, South Africa, in partial fulfilment of the award of Master of Science (M.Sc) in Science Education

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Declaration

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Signed Date

Denise van der Merwe

Abstract

The gap between theory and practice in education remains a persistent problem identified by some researchers as today's "Achilles heel of teacher education". The experience in science education is no different. Pedagogical content knowledge (PCK) has emerged as a theoretical construct that offers science education practitioners a framework to bridge the theory-practice divide because of its ability to transform content knowledge. However, little is known about how the complexity of classroom practice influences PCK acquired by pre-service teachers from structured courses. The purpose of this study was to illuminate pre-service teachers' PCK as it develops from a point of reasoning about teaching a specific topic into classroom delivery. This study was performed as a qualitative case study of 23 final year pre-service science teachers. It was located in a methodology class that had a specific objective to develop PCK in core topics of science. The students were exposed to an explict intervention on developing PCK in teaching stochiometry then placed in various High Schools around Johannesburg during teaching experience. Data collected was largely during their placement in schools. It consisted of qualitative data such as lesson plans, audio recordings of classroom teaching and self - analysis reports submitted after the teaching experience. Analysis was based on a qualitative in-depth method for identification of evidence of teaching segments illustrating pedagogical transformation. These are segments where there is evidence of two or more topic specific components of PCK defined as Topic Specific Content Knowledge (TSPCK). These were called TSPCK episodes. The TSPCK episodes identified in lessons plans and in recorded lessons were analysed for identificaton of components present and the nature of interactions. These were turned into pictorial TSPCK MAPS. The analysis of pre-service teachers' views on TSPCK were analysed through a combination of open statements and a science teacher belief tool. The findings indicated that TSPCK episodes identified in lessons plans experience an authentic expansion, blossoming into a cluster of episodes which still carried out the original intention. In some cases the intention could be seen through a similar TSPCK episode in some cases the component sequence and identity had changed. Furthermore, pre-service teachers showed positive awareness of their own level of teacher development and credited their development to the TSPCK framework. Recommendations in this report include promotion of the implementation of the TSPCK framework in Initial Teacher Education, particularly in the methodology courses with reference to classroom complexity.

Dedication

To my supportive husband, Petrus: you have been the rock I needed to fulfil all my dreams, without you I could not endure. To my son, Alex I thank you for your patience and pray that my sacrifices will inspire your successes. I thank God for both these people and the hand He has placed under us to reach all our goals.

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List of Abbreviations

PCK	Pedagogical Content Knowledge
TSPCK	Topic Specific PCK
ITE	Initial Teacher Education

Chapter 1: General Introduction to the Study

This chapter is an introduction to the study, highlighting the South African context in which the research takes place which drives the purpose of the study. I discuss the problems identified in the context, the research questions that guide it and provide brief descriptions of the chapters comprising the research report.

1.1. Introduction

The South African education system has been rated as sub-standard and failing the youth by limiting their future economic prospects (Spaull, 2013). Policy suggestions to improve the quality of education include the implementation of nation-wide teacher training (Spaull, 2013). Teacher education programmes should therefore strive to arm pre-service teachers with the skills and tools they require to deliver quality education.

One of the common goals among ITE programmes is to develop teachers who can apply their learning to actual teaching situations. What Kislov (2014) called turning the "know that" to the "know how". The gap between theory and practice in education has been identified as a perennial problem (Korthagen, 2010) that permeates through all disciplines. It is a gap identified by Darling-Hammond (1999) as the "Achilles heel of teacher education". In science education the problem is no different. The theoretical construct of Pedagogical Content Knowledge (PCK), has emerged as a widely accepted enabler, that forms a bridge between the understanding of content the "know that" and its teaching the "know how". However, there is still a long way to be travelled to completely develop a literature on how PCK could close the theory-practice gap, and actually understand what changes or transformations actually happen as a teacher moves from planning to classroom teaching (Álvarez, 2015). van Driel and Berry (2012) suggest that part of assisting pre-service teachers bridge the gap is to recognise the connections between their different knowledge bases. In the literature, efforts to uncover pre-service teachers' views on their teaching and learning have focussed on content, classroom and targets achieved, using CoRes and PaP-eRs (Loughran, Berry, & Mulhall, 2006). Pre-service teachers have been able to portray certain components of pedagogical content knowledge (PCK) but fewer studies are known about their reflection on their own teaching in relation to their planning. This study intends to bring to light the journey undergone by pre-service teachers' effort to transform content from a planning perspective into their actual classroom teaching, and actually evaluate whether they are aware of the process, and what they think about it.

1.2. Purpose of the study

The purpose of this study is to illuminate the journey of content transformation by pre-service teachers from a lesson plan into the complexity of classroom teaching. Furthermore, to determine whether pre-service teachers are able to identify the changes that happen, if any, and capture their views of the change and what it means to their learning trajectory.

1.3. Problem statement

The problem of leaving the perennial gap between theory and practice unattended, is that ITE programmes would never be able to predict with some certainty whether their graduates would be effective teachers or not. It would mean, effectiveness in the actual classroom is left to chance and luck! While PCK has grown to be acceptable by the science community as the knowledge for teaching science, particularly more effective within topics (Abell, 2008), little is actually known about the relationship between PCK seen in planning and that observed in classroom teaching. The problem lies in identifying how one kind of reasoning is expanded on from a lesson plan to how this reasoned intention plays out in an actual classroom situation. For ITE programmes, it means there is no system on knowing whether the strategies used to acquire PCK in the first place are actually effective. This study aims to trace the process followed by pre-service teachers in their learning to reason and transform content knowledge in planning, and that exhibited in actual classroom lessons. Such understanding would assist teacher development programmes to implement programmes for PCK development close to the real complexity demanded by a classroom context. Furthermore, it is important for teacher educators to be aware of the views held by pre-service teachers as they experience their learning from planning into the classroom.

1.4. Rationale

There is a global call for quality education in schools, better understanding by learners and better quality teachers (Taylor, 2015) in terms of having more knowledge of the content they teach. In science education in South Africa, the level of science education is said to be poor (Spaull, 2013) partly due to the training received by science educators at rural education colleges (Mavhunga & Rollnick, 2017).

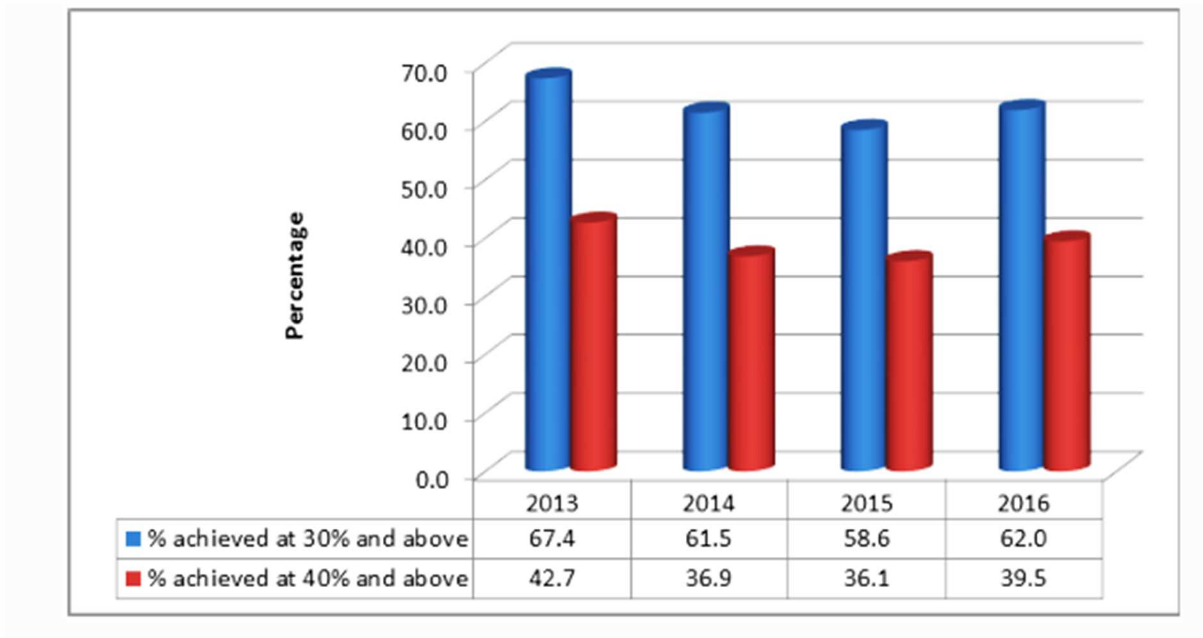

Figure 1. Overall achievement in Physical Sciences (DBE, 2016)

The Annual diagnostic report (DBE, 2016) compares the achievement of grade 12 physical science learners who wrote the NSC examinations in South Africa from 2013 to 2016 as seen in the graph above. There appears to be minimal improvement in the performance of the learners in the four consecutive years. The graph indicates that, on average over the indicated time period, only 38.8% of matriculants enrolled to write the NSC exam, were able to achieve above 40% in physical sciences. The implications of these statistics are that more than 61% of physical science learners do not perform satisfactorily and educator accountability and ability becomes questionable

Upgrading the knowledge and skills of practicing educators would require their removal from classes where learners still need their educators on a daily basis, an impossible feat. Therefore the ideal would be to fast-track the development of pre-service science teachers' knowledge and competencies to deliver understandable lessons as they enter the classroom to teach. Initial teacher education could then be seen as playing a restorative role in science education in South Africa (Mavhunga & Rollnick, 2017). PCK is a potentially promising construct to be used to implement this ideal. PCK as described by Shulman (1987) is teacher knowledge requiring application in planning and develops further in the enactment. At a conceptual level, little is documented about pre-service teachers' development from lesson plans to enactment (Mavhunga & Rollnick, 2017), allowing for further research opportunities into the extent to which planned TSPCK is translated to enacted TSPCK. This study aims to contribute towards the literature by illuminating the progress of enacted TSPCK from planned TSPCK in an effort to assist the bridging of the theory-practice gap in initial teacher education.

1.5. Research questions

This study is guided by the following main research question:

What changes, if any, does TSPCK observed in lesson planning undergo when the well reasoned lesson plans are enacted out in the complexity of classroom practice?

The main research question is investigated through three sub-questions:

i. What patterns of TSPCK component interactions are observed emerging from pre-service science teachers' planning and actual classroom teaching of a physical science topic?

ii. How do such patterns differ from those reported by pre-service teachers from their self-analysis of their planning and its enactement into classroom practice?

iii. What views do pre-service teachers hold about the value of TSPCK in their teaching, particularly with respect to changes in their TSPCK (if any) from planning to practice?

1.6. Outline of the research chapters

This study comprises of six chapters. In this, the first chapter, I presented an argument showing the problem in science education teacher training presented from a South African viewpoint. The rationale suggested the potential contribution of the study to existing TSPCK literature The problem statement prompted the formulation of the research questions guiding this study which informs the choice of literature review, theoretical framework and the research design the second chapter is the literature review. Here I cover aspects such as the theory-practice gap in initial teacher training, reflection as a means to bridge the gap and PCK as a means to close the gap in science education. The choice of aspects discussed stems from the nature of the research question and my interest in the development of science pre-service teachers. I close the chapter with a discussion of my theoretical framework.

Chapter three describes the research methodology and research methods used to gather data for analysis informed by the research questions and theoretical framework. Chapter four analyses the data with regard to illuminating the nature of the emerging TSPCK episodes in actual classroom teaching as compared to the episodes pre-service teachers planned to teach. The fifth chapter analyses the views held by pre-service teaching about their TSPCK and views about science education. The final chapter provides an overview of the study, discussing the findings in terms of the research questions, with care given to the validity and trustworthiness of the findings made. The conclusion will propose recommendations for the improvement of teacher education programmes in the future.

Chapter 2: Literature Review

This chapter outlines the literature which has been chosen on the basis of the purpose of the study. In this study I reflect on few aspects related to the development of pre-service teachers, all however, speaks to the perennial problem of the gap between theory and practice. I touch on quality of education in South Africa, views held by science pre-service teachers, teacher professional knowledge for teaching science and close with a discussion on a theoretical framework.

2.1. Introduction

2.1.1 Theory-practice gap in education and science education

Upon enrolling in initial teacher education programmes, students and teacher educators work towards the graduation of capable teachers (Hume & Berry, 2011). Pre-service teachers receive the bulk of their training as lectures focusing on educational history and pedagogical theories (Alexander, 2010). The practical application of these conceptual theories in a classroom situation is often far removed from the theories taught during teacher training, with varying complex classroom contexts, hence the theory-practice gap (de Swardt, du Toit and Botha, 2012 Álvarez, 2015). The connections between theory and classroom practice has often been left to pre-service teachers to figure out by themselves (Nilsson, 2008). The problem is compounded by the misconceptions pre-service teachers often about their content and their role in applying the acquired knowledge in practice (Mc Donough, 2012). This leads to the common observation that graduating pre-service teachers enter the teaching arena with less confidence and ill-equipped for the challenges of dynamic teaching situations in classrooms (Botha & Reddy, 2011). In the South African context, there is no coherent and effective induction programme for beginner teachers meaning that the theory-practice gap experienced by a beginning teacher may take a very long time to be mediated, if at all.

Suggestions by educational researchers into narrowing the theory-practice gap point toward practical perspectives of teaching. McDonough (2012) and van Zyl (2014) advocate teacher education programmes which provide opportunities for pre-service teachers to implement theory in a practical form that would foster critical thinking and problem-solving skills. Gravett

& Petersen (2015) promote guided learning in teaching-schools with extended teaching experience, allowing for reflection on these experiences. Loughran & Hamilton (2016) suggest systemising pre-service teachers' pedagogical thinking toward conscious reflective practices regarding their pedagogical reasoning. The development of pedagogical content knowledge, using specific tools including CoRes (Loughran et al. 2004) and PCK maps (Park & Chen, 2012) enable pre-service teachers to reason about the transformation of their learnt knowledge as they plan to teach it in their classrooms narrowing the chasm between learning and doing.

2.1.2. Reflective teaching working toward closing the theory-practice gap

Dewey (1910) defined reflection as a process of deliberate practice involving, not only a sequence of ideas, but a consecutive ordering of ideas, each determining the next, but referring to the idea upon which it was built until there is a sustained train of thought leading to a common end. Schőn (1983) described the act of reflection as a process of reframing problematic contexts in order to develop alternative ways of acting. Reflection is an act of thinking about past experiences in order to apply the knowledge gained in hindsight to ensure better future experiences (Shulman, 1987). Teachers perform regular reflections on teaching episodes to determine the success of lessons, and to assist them in correcting practices they feel may have hindered the understanding of their students. Goldman and Grimbeek (2015) state that self-reflection is promoted among all teachers in modern educational literature as an action ensuring that students experience quality teaching.

Without reflection, teachers would possibly be in danger of repeating the same teaching practices over and over again, whether these practices assist student learning or not. It is not an advantageous position to be in as a teacher who has one year's teaching experience several years running! There would be no growth for the individual teacher, the way in which the subject matter is taught or student advances in understanding. As Barry and King (1998) stated it, "self-evaluation is the hallmark of professionalism!"

Quality teaching occurs when a teacher knows what to teach and how to teach it under often varying conditions. Knowledge to deliver quality teaching cannot be transferred to another person in a single teacher training programme, it must be developed with time and teaching experience (Morris, 2006). John Dewey (1966) noted that knowledge is constructed when prior knowledge interacts with new experiences, developing connections between them in order to move forward. The teacher can therefore improve on each teaching episode by mentally returning to the actions of the previous teaching and learning experiences in order to make decisions informing future actions. According to Morris (2006) the central skill in learning from practice is to analyse teaching in terms of its effects on learning. The teacher needs to ask the questions, “What do students learn from particular instructional activities, and how do the activities facilitate the learning?” These questions embrace the concept of thinking about teaching actions in order to find their answers. Lesson reflections allow teachers to analyse teaching and enable teacher educators to determine the level of skills pre-service teachers have in order to inform teacher education programmes (Morris, 2006).

The focus of this study is on the reflective skills of pre-service science teachers, who by definition have not accumulated sufficient service time to build a repertoire of episodes upon which they can reflect to enhance their teaching strategies. It is the aim of this study to use pre-service teachers’ self-reflective skills, based on the analyses of their own documented teaching episodes in to illuminate how they can make informed choices in the development of future teaching practices, enhancing their effectiveness as teachers early in their careers.

2.1.3 Professional teacher knowledge (PCK)

Shulman (1986, 1987) initially defined PCK as the knowledge teachers use to teach to make the subject content more understandable for learners. He described it is a synthesis of subject matter knowledge, SMK; pedagogical knowledge, PK and knowledge of context.

PCK is often specific to the teacher who teaches it, with a teacher understanding what is to be learned (content knowledge, CK) and how it is to be taught (PCK). Aspects of PCK are therefore personal as teachers themselves decide how to phrase their statements and questions and their examples, demonstrations, analogies as well as which memory enhancing strategies to apply (Mavhunga and Rollnick, 2013). Kind (2009) added that PCK implemented by teachers relates to the amount of learning achieved by the learners, an indication of good science teaching. She also noted that this construct was elusive and that limited consensus existed regarding the nature of PCK among educational researchers, opening an opportunity for researchers to finally set forth a more integrated model as a canonical knowledge base of teachers.

2.1.4 PCK bridging content and pedagogy gap

Key research findings of McDonald, & Dominguez (2010) show that, in order to prepare effective teachers, both the knowledge of the subject taught and the 'knowledge and skill in how the subject should be taught, which is PCK, should be presented to them in an ongoing fashion. Research studies have shown little in the way of the mechanism of how student teachers develop PCK, therefore it is important to make explicit the factors contributing to pre-service teachers, development of knowledge of how to teach (Nilsson, van Driel, 2011). According to Nilsson and van Driel (2011), teacher education programmes offer pre-service teachers the first opportunity to reflect on the use of their content knowledge. Reflection of this nature enables pre-service teachers to gain an awareness of their understanding of the content, the structure and nature of the discipline and the skills they need in order to transform the facts into an understandable form for learners (Nilsson & van Driel, 2011). Nilsson and Loughran (2011), used CoRes as support for planning and assessing their own learning about teaching, upon examination it could be seen that pre-service teachers had developed their skills when they were involved in collecting evidence of their achievement and learning how to identify their strengths and weaknesses, becoming actively involved in the process of learning about teaching. Mc Duffie (2004) stated that once pre-service teachers have learnt how to analyse their teaching practices, long-term reflection should be encouraged in pre-service teachers, since it will equip them to put together the pieces of individual reflective episodes to revealing the pattern that can inform their practices, in time, allowing them to sustain professional growth. By encouraging pre-service teachers to reflect on their own teaching they may develop insights into their thinking about the science content, science teaching and their professional development. There exists a need to explicate the knowledge used for teaching and to establish ways of thinking about science teaching beyond the mere accumulation of pedagogical strategies.

2.1.5 A move from PCK to TSPCK

Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) presented a model of PCK that showed how PCK may manifest at classroom level. This model was expanded upon by Mavhunga (2012) who defined PCK in a specific topic as a theoretical construct termed Topic Specific Pedagogical Content Knowledge (TSPCK). More recent studies shed more light on the specific knowledge that gives PCK its topic specific nature (Mavhunga, 2016). Park and Chen (2012) explored the integration among PCK components for two different biology topics, photosynthesis and heredity. The authors counted the frequency of connections among the PCK components. The results of the study showed that integration among the components was topic-specific as the more component interactions were observed for the photosynthesis topic than in the heredity topic. Furthermore, the PCK components of knowledge of learner and knowledge of instructional strategies were found to have the strongest interactions and were more explicit in the teachers' PCK for both topics. A similar study using the PCK pentagon model on chemistry topics was conducted by Aydin and Boz (2013). The authors observed the interaction of the PCK components in two experienced chemistry teachers' teaching of electrochemical cells and redox reactions. Their findings confirmed the observations by Park and Chen (2012) that the PCK components of knowledge of learner and knowledge of instructional strategies played a more prominent role in the PCK of the teachers' in both topics. Common across these studies is the realization that the topic-specific nature of PCK emerges from components that are content specific, such as knowledge of students' and conceptual teaching strategies in specific contents, rather than those that particularly refer to discipline, such as assessment and orientations. The findings of the above cited studies, in a way, provide empirical evidence to the idea of PCK experienced at different levels, as suggested by the PCK taxonomies of Nezvalová (2011) and Veal & MaKinster (1999).

Mavhunga (2012) developed a model that portrays the transformation of content knowledge from five content specific components, Figure 2.1 below.

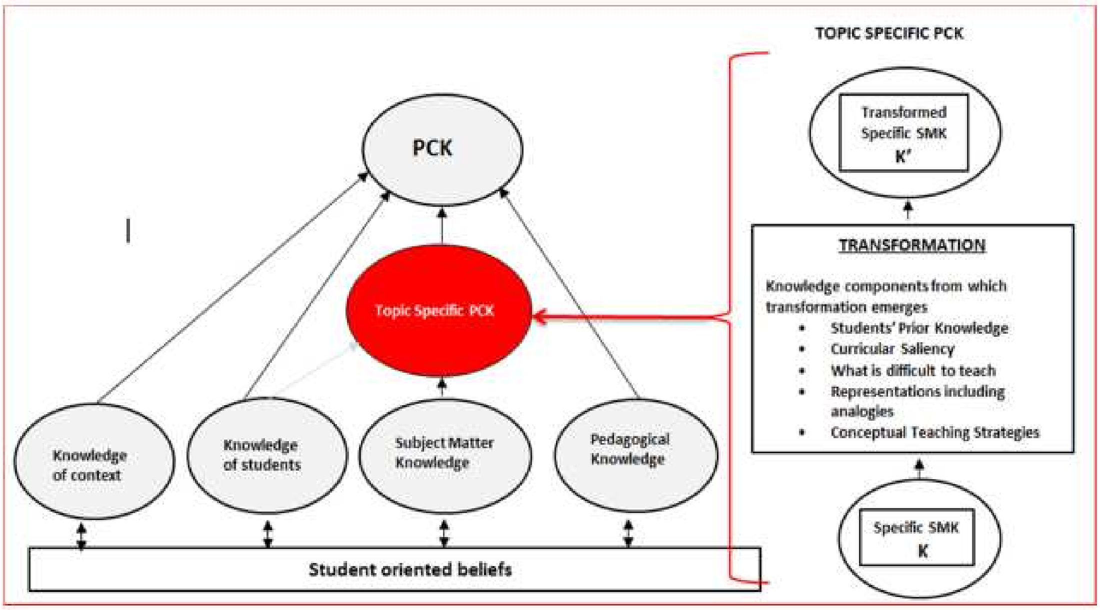

Figure 2.1. The Mavhunga (2012) model of TSPCK

The Mavhunga (2012) TSPCK model comprises of five knowledge components which enable the teacher to effectively transform subject matter knowledge:

1. Learner Prior knowledge.
   Learners' knowledge about a particular topic before the lesson begins. This knowledge includes any misconceptions or alternative conceptions a learner may have.
2. Curricular saliency.
   This is the understanding of which topics are central or peripheral relative to the curriculum as a whole.
3. What is difficult to teach or understand.
   Specific concepts in a topic that require conscious intervention by the teacher during classroom teaching.
4. Representations.
   Examples, analogies, simulations or models used to represent subject matter.
5. Conceptual teaching strategies.
   Effective instructional strategies used to address difficult or important concepts.

Mavhunga (2012) asserts that when teachers reason about their teaching, they consider a topic from the perspective of the five content specific knowledge components. The model offers a way to picture PCK at a topic level. Shulman's (2015) review of the theoretical construct of PCK during the first PCK summit confirmed the domain specificity and contextualisation nature of PCK. The Mavhunga model (2012) also acknowledges the influence of teacher beliefs into the way a teacher would reason through their teaching. Thus, assisting pre-service teachers to recognise components of TSPCK and develop teaching strategies according to more learner-centred beliefs, will better equip them for entering the teaching profession, enhancing the performance of learners in their classes.

2.2 Theoretical framework

The theoretical framework for this study is grounded on Shulman's (1987) description of the transformation of content knowledge for effective classroom teaching theoretical concept of PCK, particularly at a topic level. Thus the model by Mavhunga (2012) defining the TSPCK construct was found more suitable. The need to transform content knowledge is mentioned by Geddis (1993) as crucial in ensuring effective teaching and learning take place in the classrooms. I also draw on the consensus model of PCK (Gess-Newsome, 2015) Figure 2.2 that presents the interrelatedness of the knowledge of the teacher to practice and to learner outcomes. I focus on the layer of Topic Specific Professional Knowledge that speaks to the topic specific nature of PCK. I use the components of TSPCK from Mavhunga (2012) as elements of this layer

According to Gess-Newsome (2015) the teacher professional knowledge base (TPKB) informs and is informed by topic specific pedagogical content knowledge (TSPCK) therefore, although these knowledge bases are generic, their power lies in teaching applications to a specific topic.

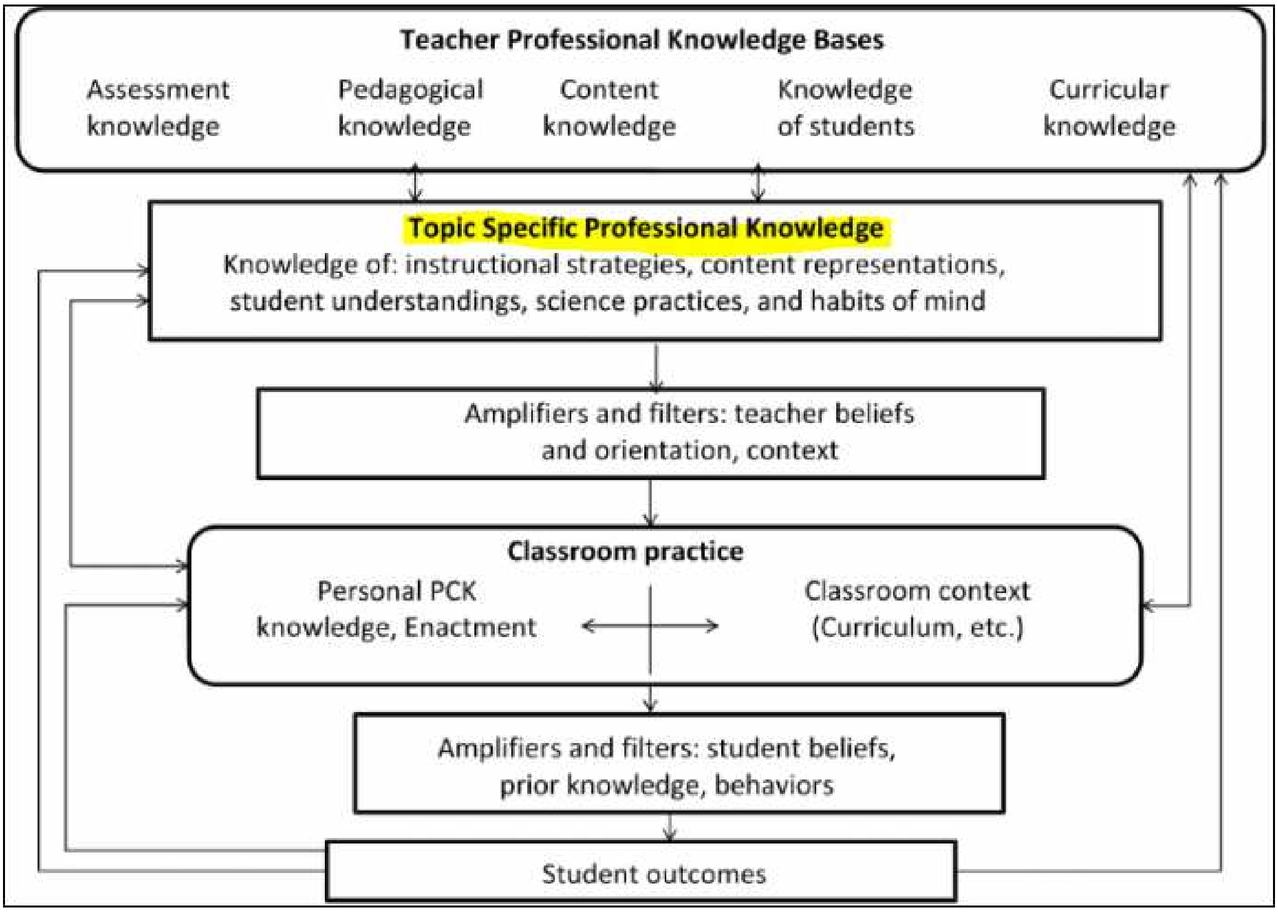

Figure 2.2. Model of the teacher professional knowledge and skill including PCK (Gess-Newsome, 2015)

Topic specific professional knowledge is recognised as a professional knowledge category that informs all subsequent teaching and learning activities to achieve learner outcomes (Gess-Newsome, 2015). The consensus PCK model also recognises that teacher beliefs and orientations contribute to actions in the classroom (Gess-Newsome, 2015). According to Gess-

Newsome (2015), the personalisation of knowledge by a teacher, whether to accept or reject certain parts of the content or practices are based on the beliefs and views teachers hold. These factors are part of the filters and amplifiers that can be taken into account when observing PCK in practice and will aid in obtaining more understandable findings with less unexplainable data. The one other value derived from distinguishing PCK at a topic as presented in the consensus PCK model is that it acknowledges content specific components that could be considered in capturing and measuring PCK at a topic.

2.3 Capturing and portraying TSPCK in planning and teaching

PCK is a tacit construct (Loughran et al. 2006), personal to the teacher reasoning about the transformation of the content to be taught (Shulman, 1987). In order to have a sense of its measure it needs to be observed in different contexts at least in planning and enactment. Equipping pre-service teachers for the classroom by developing their TSPCK using reflective practices would require teacher educators to work from an explicit knowledge base of TSPCK revealed. As prior learner knowledge informs a teacher in lesson scaffolding, so too would evidence of pre-service teacher TSPCK inform further development of the construct in teacher education programmes. Efforts to capture and record this personalised teacher professional knowledge reveals insights into the pedagogic reasoning required to transform content knowledge.

Nezvalová (2011) found that action research allowed the researcher to place themselves in the practices of pre-service teachers, allowing insight into pedagogical events. Unfortunately the individualistic nature of each case makes formalising the events into a canonical knowledge base difficult. Strategies to document PCK included PCK multiple choice questions, concept mapping, semi-structured interviews, pictorial representations and video-observations, each with their own set of challenges with regard to either developing, administering or analysis (Zhou, Wang & Zhang, 2015). Content Representations (CoRes) and professional experience repertoires (PaP-ers) showed great promise (Loughran et al. 2006), raising pre-service teachers' awareness and understanding of PCK, enabling them to articulate PCK aspects as they plan to teach lessons for the first time (Hume and Berry, 2011). In recent studies aimed towards portraying PCK, pre-service teachers and practising teachers were given the opportunity to articulate their PCK through videos, designed pencil and paper tools for PCK in specific topics like chemical equilibrium chemistry (Mavhunga and Rollnick, 2013), particulate nature of matter (Pitjeng, 2013) and Stoichiometry (Malcolm, 2015). Each capturing method aims to make PCK considered in a topic more explicit.

There is, however, still a need to show how the planned PCK emerges during the actual teaching of the planned lessons. Park and Chen (2010) designed PCK maps to illustrate the interaction of PCK components during classroom teaching, making PCK explicit for the topics taught. Mavhunga (2015) has used the PCK maps to demonstrate the nature of interaction of TSPCK components in the planning and subsequent teaching of lessons. This study continues to build on this relatively new research path, with the use of TSPCK maps to demonstrate the emergence of pre-service teacher pre-service teacher's awareness of their learning through the planning and teaching of specific topics using interacting TSPCK components.

2.4 Pre-service teacher views about education and preparation for teaching

Several science education researchers (e.g. Gess-Newsome, 2015), noted that the views held by teachers have an influence on the transformation of content and delivery in the classroom. Teachers may present the same content to learners in different ways informed by their views, emphasising selected aspects and discarding certain teaching approaches. The beliefs of a teacher seem to have notable impact on the teaching and learning process. Gess-Newsome (2015) placed teacher beliefs as filters and amplifiers in the PCK consensus model due to the strong influence certain beliefs have on the transformation process. Therefore, the views held by teachers strongly informs the portrayal of PCK in planning and enacted teaching episodes to the extent that it warrants investigation concurrently with the emergence of TSPCK components. Luft and Roehrig (2007) note that educational researchers have equated beliefs with terms including attitudes, knowledge, philosophies or views. Nilsson and van Driel (2011) describe the interconnectedness of views and the beliefs that inform them through reflective practices. In this study the reflective practices of pre-service teachers, beliefs and views will be considered for the insight they offer about how pre-service teachers think about their knowledge.

In summary, an increased awareness of the interaction of TSPCK components during planning and teaching could contribute to the maturing views pre-service teachers hold about teaching, strengthening their teaching capabilities as they enter the teaching profession.

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Chapter 3: Research Methodology

This chapter presents the methodology employed in this study. The chapter begins with a revision of the research questions guiding the study, the approach used to guide gathering of the data and its consequent analysis that strived to answer the research question. This chapter describes the participants, the method of data collection, the type of data collected, and how data were analysed to lead to the key findings made in this study. Mention of the ethical considerations, validity and reliability are made in order to establish the trustworthiness of the study. In conclusion, the chapter summarises the research methods in order to give clarity to the findings mentioned in the next chapter.

3.1. Introduction

In this study I sought to illuminate pre-service teachers' TSPCK as it develops from reasoning about teaching a specific topic into their classroom delivery. The starting point acknowledges that the classroom teaching process is not simply a transmission of the reasoned plan, nor an additive process but requires competence in transforming content knowledge as a core practice in science education (Grossman, Hammerness, & McDonald, 2009). In the backdrop of the theory-practice divide mentioned earlier, this study posits that the success towards narrowing the theory-practice gap in science education lies in fully understanding the classroom implementation of acquired TSPCK. As a result, the study asks the following question:
What changes, if any, does TSPCK observed in lesson planning undergo when the well reasoned lesson plans are enacted out in the complexity of classroom practice?

The main research question is investigated through three sub-research questions:

I. What patterns of TSPCK component interactions are observed emerging from pre-service science teachers' planning and actual classroom teaching of a physiccal science topic?
II. How do such patterns differ from those reported by pre-service teachers from their self-analysis of their planning and its enactement into classroom practice?
III. What views do pre-service teachers hold about the value of TSPCK in their teaching, particularly with respect to changes in their TSPCK (if any) from planning to practice?

3.2. Research design

This study employs a qualitative research method which falls under the interpretivist research paradigm. Qualitative data analysis allows for rich data descriptions (Opie, 2004), enabling identifications of themes and patterns but can unfortunately not be generalised and will remain specific to the case study. This research method is suitable for my study that seeks to gain insight into reasoning about tacit theoretical construct such as TSPCK, and establishing the views held by pre-service teachers about their science teaching. The research strategy, used to answer the research questions guiding the study (Bertram & Christiansen, 2014), is a case study, a systematic, in-depth study of a particular case in its context (Rule & John, 2011, Cohen, Manion & Morrison, 2000). The advantage of using this strategy is that it allows an in-depth investigation into the tacit theoretical construct that is TSPCK. As a case study limits generalisation of findings (Cohen, Manion & Morrison, 2000) my sample participants included the entire cohort of fourth year students in the methodology class in order to add strength to the identified patterns discovered during analysis.

3.3 Background to Participants

The participants in the study were 23 final, fourth year science education students attending a university in Johannesburg, South Africa in 2015. The university offers the B. Ed teacher qualification degree, where both the content courses and methodology courses are taught in the same department. All participating pre-service teachers originated from disadvantaged communities in South Africa and attended that particular university since their first year of teacher education. The participants all shared a common goal of majoring in physical science at the end of the academic year.

3.4. Treatment received

The chemistry methodology course has as its core objective the development of TSPCK in core topics of chemistry and physics. Mavhunga and Rollnick (2017) documented the intervention as a signature treatment assisting with the development of specialised professional teacher knowledge one topic at a time over a six-week period. The topic used in 2015 was stoichiometry. At the heart of this intervention is the development of an understanding that teaching as a practice involves transformation of the teacher's understanding of content knowledge. In the treatment, pedagogical transformation of content knowledge is achieved through the introduction of the five components of TSPCK and also learning to use them interactively in formulating explanations. The components were introduced in the sequence: Learner Prior Knowledge; Curricular Saliency; What is difficult; Representations and Conceptual teaching strategies. Each component discussed over 3 hours in a week. The final week was used to emphasize interactions among the components. In addition, they were introduced to the in-depth qualitative analysis method for evidence of TSPCK episodes in their planning to teach efforts. They were further exposed to reflective practices that required open statements in various tutorial submissions. Teacher science beliefs were also mentioned to them as influencing teachers' orientation towards teaching, but no detailed discussion on them was done. Upon completion of the intervention, pre-service teachers were placed in secondary schools near Johannesburg for teaching experience where they applied their knowledge during planning and actual teaching of lessons. In the schools, pre-service were to teach various different physical science topics according to the plan of the placement school.

3.5 Data collection

Data was collected late in 2016, retrospectively from the archives of the methodology course where pre-service teachers received treatment. These included their teaching plans and thick descriptions of their lessons where they indicated the TSPCK components present in the teaching episodes in the form of TSPCK maps (Park & Chen, 2012). Teaching episodes were defined as instances during planning or teaching where there is evidence of two or more interacting TSPCK components present (Mavhunga, 2014). An examination equivalent completed by the pre-service teachers at the end of the methodology course contained their views regarding teaching, the construct of TSPCK and their development as teachers.

The qualitative data collected comprised mainly of the following:

- Lesson plans from teaching experience
- Transcripts of audio recordings of actual classroom lessons corresponding to lesson plans
- Submitted-self-analysis reports. These were reports where pre-service teachers analysed their planning vs. their actual teaching during teaching experience.
- Completed science teacher belief tools
- Open statements reflecting on the value of TSPCK.

(i) Details of Lesson plans

The lesson plans were prepared 23 by pre-service teachers during their placement on teaching experience based on the topics they would be teaching at their placement schools.

(ii) Details on Transcripts of audio

Lessons taught by 23 pre-service teachers were audio-recorded. This served as the information source they would use to identify TSPCK episodes and the components they comprised of.

(iii) Details on submitted self-analysis report

23 Pre-service teachers used the lesson plans and classroom transcripts in order to identify TSPCK episodes. Analysis of these episodes entailed listing of the TSPCK components found in each episode and mapping out the interactions between the components in the form of TSPCK maps. The pre-service teachers completed their self-analysis by commenting on the TSPCK evident in their teaching.

(iv) Details on completed science teacher beliefs

At the end of the methodology course, pre-service teachers wrote an examination equivalent containing open-ended questions regarding their beliefs about teaching and science education.

(v) Details on open statements

The research reports of pre-service teachers' analysis of TSPCK episodes contained open statements about their use of the TSPCK components in their lesson planning and actual classroom teaching. Many of these statements reflected their beliefs about science teaching.

Upon receipt of completed projects and examinations, each student's project was assigned a specific pseudonym, with all references made to the responses on these reports and exams discussed using the pseudonyms to distinguish the respondents from each other. Electronic scans were made of each page for safekeeping purposes. Cover pages containing personal information of the participants were removed and stored separately in order to maintain the anonymity of the pre-service teachers.

3.6. Analysis

3.6.1 Analysis of TSPCK episodes in lesson plans and audio recordings.

The study of measuring TSPCK levels of pre-service teachers is relatively new, therefore I followed an in-depth qualitative analysis method of gathering data of the construct. In this method, a teaching segment that contains a TSPCK episode is first identified. A TSPCK episode is defined as evidence of two or more TSPCK components interacting together. In lesson plans, this was done by content analysis of plans, in audio recordings this was done by extracting specific extracts. The identified teaching segments are first analysed for identity of the components of TSPCK present. Then, analysis is made to describe the sequence in which the components emerge e.g. one after another (linear form) or interactively. The description of the sequence gives insight into the nature of the TSPCK episode. The analysis is presented as a TSPCK map. A TSPCK map is a pictorial presentation exhibiting the way in which the components that are present interact (Park and Chen, 2012). Each component in the TSPCK MAP was represented by a labelled circle, the labels being abbreviations of each TSPCK component. The components were abbreviated as follows:

LP- Learner Prior knowledge

CS- Curricular Saliency

DIF- What is difficult to understand

R- Representations

CTS- Conceptual Teaching Strategies.

Two raters analysed the data for TSPCK Episodes following a discussion on rules for coding. An example is given below.

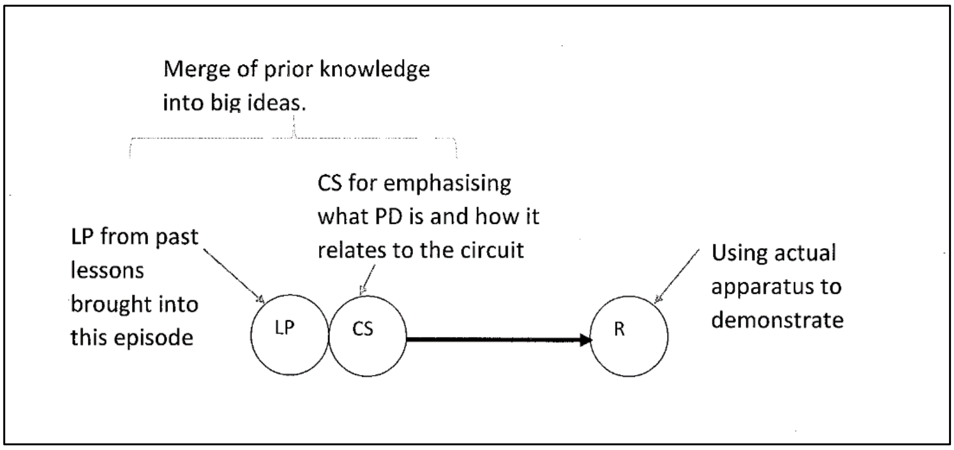


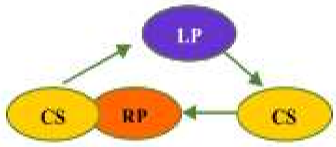
Figure 3.1. Example of a typical TSPCK map

The TSPCK map shows three components present, LP, CS and R. The touching of the component circles represents a link between the components, whereas the arrow indicates the direction of the sequence in which the components feature in the episode based on the writings in the lesson plans or the transcripts of the actual lessons.

3.6.2 Analysis of the comparison of TSPCK in lesson plans vs classroom.

I tabulated the two sets of TSPCK maps. Firstly, I analysed the TSPCK maps according to how the pre-service teachers had described to authenticate the components listed by the pre-service teachers in each teaching episode. I determined which TSPCK components were used by pre-service teachers for planning vs. teaching, searching for correlation between their planning and practical maps and accuracy of the components they listed according to the working definition of TSPCK and the components according to the Mavhunga (2012) model. The TSPCK episodes were finally matched based on intentions from planning to enactment, and analysed in terms of the nature of the component interactions in the context of the lesson topic. Table 3.1 shows an example

Table 3.1 .Lesson transcript and accompanying TSPCK map constructed by Jane

Transcript from the classroom lesson	TSPCK map
Teacher: Anybody who can tell me what a pulse is? Learner: it is a disturbance... Teacher: Anybody to add...it is not enough...add some more. Learner: it is a disturbance after a long period of time. Teacher: You are going too far away, let me just show you the definition of a pulse. I then show them the definition of a pulse from the OPH that I was using to teach before I explain it to them. After exposing the definition, I explained the definition of a pulse. This curricular saliency (CS) overlapped with conceptual teaching strategy (CTS) occurred between 00:55 seconds – 02:00 minute. Teacher: A pulse is a single disturbance which moves through the medium. For example, if you tap the water in a bucket with a finger, you will notice a ripple moves away from the point where you touched the water. Therefore a ripple is a pulse that moves away from a point of disturbance. A pulse is a single disturbance that moves through a medium. A new concept of 'medium' jumped into play and I had to define it. But before I defining it, I asked learners what they understand about the word 'medium'. I was trying to find out whether or not they know the concept – exposing learners' prior knowledge (LP) of the medium. Teacher: Now anyone who can tell me what a medium is? Because we are talking about something new… we are introducing something called a medium… what is a medium? (02:05min – 02:45min) Learner: a medium is something that can move the pulse. After a learner has responded positively to the question, I showed them clear definition of a medium from the slide and read it out to them. I emphasized this definition by repeating it three times because I realised that it is difficult for learners to understand (WD). This component overlapped with the curricular saliency (CS) and was important because learners should know that pulse needs something to move it from one point to the other. Teacher: yes that's the answer… a medium is a substance or an object that allows the pulse to move… a medium is a substance or object that carries or allows the pulse to move (repeated x3)… the medium is a substance or materials in which the pulse moves… the medium carries pulse from one place to the other. However, the medium does not create a pulse and is not a pulse. (02:45 – 04:45). I then did a demonstration – macroscopic representation (RP): I took a duster and gave it to the first learner in front and asked her to pass it to the learner next to her. The next learner	

Jane used the transcript of a lesson on pulses in order to identify the TSPCK components used to deliver the lesson. She then constructed the accompanying TSPCK map in the right hand column, depicting the interaction between these identified components.

The research projects of the 23 participating pre-service teachers were analysed with respect to the TSPCK maps they designed for the planning phase of their lessons and the actual teaching of those lessons in order to identify emerging patterns in the cohort. For presentation of analysis, four participants were identified from the data as most clearly representing the emerged patterns from the analysis process to be set out in this project, although reference to examples from the other participants have been made when assistance was needed to highlight points of importance

3.6.3 Analysis of self-analysis reports

Final year physical science pre-service teachers were required to complete mini-research projects identifying and analysing the quality of TSPCK by reflecting on their teaching experiences. They were expected to describe the TSPCK episodes and corresponding MAPS of their planning and teaching of their topics presented at their teaching experience. They also defined TSPCK episodes as instances in planning or teaching where two or more TSPCK components were found operating together in a teaching segment of a lesson. For their analysis, the pre-service teachers identified TSPCK components in their planning by compiling TSPCK maps. Pre-service teachers then transcribed audio recordings of actual classroom lessons to find evidence of TSPCK episodes from their teaching experiences and drew accompanying TSPCK maps. The created TSPCK maps were used by pre-service teachers to describe how the evidence in the lesson plans and classroom lesson transcriptions were evidence of TSPCK. They then wrote reflections on the process, including what their beliefs about their own knowledge as pre-service teachers were, and their progress and abilities after completing the course.

I analysed these reflections of each report in order to determine the recurring themes coming to the fore in the development of the pre-service teachers. I also analysed these reports to indicate whether I agreed with the analysis, following the in-depth qualitative analysis technique based on the evidence, such as the extract or description presented by the pre-service teachers.

3.6.4 Analysis for pre-service teacher views

In this study I considered 'views' as a combination of freely expressed statements and science teacher beliefs. Teacher beliefs are personal constructs that provide understanding of the teacher's practices (Luft & Roehrig, 2007) serving as a lens for class activities, enabling teacher education programs to continue developing science teachers. Nilsson and van Driel (2011) describe the interconnectedness of views and the beliefs that inform them through reflective practices. Luft and Roehrig (2007) previously explored teacher beliefs by conducting semi-structured interview with teachers to document teacher beliefs. They asked key questions given below:

1. What does teaching science mean to you?
2. How can you increase chances for student learning in your science classroom?
3. Describe how you perceive your role as a science teacher?
4. During your school teaching experience, how did you know when your students understood what you taught them?
5. In a school setting, how do you decide what to teach and what not to teach?
6. How do you decide when to move on to a new topic in your classroom?
7. How do your students learn science best?
8. How do you know when learning is occurring in your science classroom?

My study analysed the responses on these questions by employing the science teacher belief MAPS designed by the authors (Luft and Roehrig, 2007) for analysis. The MAPS are criterion based and required matching of pre-service teachers' responses with the criteria to determine the category. According to Bertram and Christiansen (2014) the method chosen to analyse the data must be the most effective in obtaining the information needed to answer the research questions. Although the use of an open-ended questionnaire has the disadvantage of being unable to fully explain why a certain response was given, the value of using a structured questionnaire such as the science teacher beliefs containing closed ended questions, yielding quantifiable information about the group would not have elicited the descriptive responses from the participants required to answer the research questions (Bertram & Christiansen, 2014).

Using the rubric to analyse the beliefs elicited by pre-service teachers in the test answers would allow me to gain insight into their thinking that cannot be captured through observation of teaching activities (Luft & Roehrig, 2007). Ahmed, Lubben & Sadeck (2014) performed a similar study eliciting data from teachers expressing their opinions and views on the use of socio-scientific scenarios in science teaching, and searched for similarities in the respondents' answers to find patterns of similarities in responses. I am searching specifically for evidence of the use of TSPCK and reform-based teaching beliefs in their answers, and find it more appropriate to place these as criteria in the rubric to narrow the search specifically for these items. Jonsson & Svingby (2007) studied the advantages of the use of rubrics in educational research and concluded that rubrics are a reliable scoring tool, especially if they are analytic and topic-specific. Rubrics make the criteria of the study specific, facilitating feedback (Jonsson & Svingby, 2007). There are limitations to the instrument I am using as the identification of teacher beliefs is a difficult task given the concern that participant responses to the questions may represent the intention to perform certain behaviours and the behaviours that they would perform in reality. Jonsson and Svingby (2007) mention that a drawback of rubric use lies in the validity of judgement of performance assessment, requiring a more comprehensive framework of validity if the rubric is to be validated.

The data collected is called textual data, but can be converted to numerical data to identify pattern formation and can be difficult to analyse therefore, care should be given to the tool that analyses the responses given, reason being that the researcher can struggle to compare responses that have little in common (Cohen, Manion & Morrison, 2007). Therefore, I found it to be a better option to analyse the answers according to a rating scale from traditional-type views to reform-based answers according to the type of descriptors I used to describe different forms of the same type of category in the rubric. Therefore, each category of answer was allocated at least three descriptors depicting the category to allow for the variances in the types of answers given by the participants, to still be described according to the categories.

Below is a segment of the rubric, with the entire rubric to be found in Appendix 3.

<table>
<tr><td colspan="6">1. What does teaching science mean to you?</td></tr>
<tr><td colspan="6">Evidence of awareness that teaching requires transformation of content</td></tr>
<tr><td colspan="3">Transformation of content mentioned</td><td colspan="3">No transformation of content mentioned</td></tr>
<tr><td colspan="6">2. How can you increase chances for student learning in your science classroom?</td></tr>
<tr><td colspan="2">Teacher focused</td><td colspan="2"></td><td colspan="2">Student focused</td></tr>
<tr><td>Traditional
Teacher provides information in a structured environment.</td><td>Instructive
Teacher monitors student actions during teaching</td><td colspan="2">Transitional
Teacher creates a classroom environment that involves the student</td><td>Responsive
Teacher designs the classroom environment to enable students to interact with each other and their knowledge.</td><td>Reform-based
Teacher depends upon student responses to design an environment open to individualised learning</td></tr>
<tr><td>• “By carefully planning my lessons”
• “By using PowerPoint presentations”
• “By arranging the classroom so that the students face me”
• “I use a textbook, a study guide and we have it on the web”</td><td>• “By looking at students’ responses”
• “I watch my students closely as they complete lab activities”</td><td>Cognitive
• “By using different types of activities”
• “By encouraging them to do their own thinking”</td><td>Affective
• “By building a positive, supportive environment”
• “By having a relationship with students outside of class”</td><td>• “By using small group activities in which students hypothesise, predict, create, share and question”
• “By giving students the opportunities to defend their ideas in front of their peers”</td><td>• “Knowing that not all students learn in the same way, I need to organise the lesson in different ways”
• “By allowing students to choose their own vehicles to learn by”</td></tr>
</table>

Figure. 3.2: Extract of the adapted Beliefs rubric.

The analysis of pre-service teachers' open statements of reflections on TSPCK were analysed through content analysis.

3.7 How validity and trustworthiness was ensured

Trustworthiness in this paradigm is ensured by detailed descriptions of the data (Bertram & Christiansen, 2014), and data has been kept authentic and I have attempted to reflect the experiences of the participants as accurately as possible. At the beginning of the in-depth analysis, a second rater analysed some of the participants' TSPCK maps in order for an agreement to be reached regarding the coding and analysis of the maps and rubric of teacher beliefs. For this reason, whenever an analysis was made, an extract of the original document was included in the analysis tale with sections leading to the analysis highlighted to indicate how the deduction or identification of the component or episode was made to attempt to eliminate the shortcoming of multiple interpretations of the data. The beliefs rubric was adapted from an original, piloted and proven rubric by Luft and Roehrig (2007) ensuring the trustworthiness of the data on teacher beliefs.As a result, validity was enhanced in order to ensure that the interpretations of all data sets were authentic and convincing to other researchers.

3.8 Ethical issues

Before analysis of existing reports, I applied for ethical clearance, see appendix 1, to perform the research. Data collection assured individual anonymity and preservation of confidentiality. The names of the pre-service teachers have not been used for analysis purposes as pseudonyms have been assigned. Each participant received an information sheet, explaining the nature of the research project. Participants were asked to sign a letter of consent, agreeing to be part of the study, and to be audiotaped during the interview process. The risk identified is low to the participants due to the fact that they have already completed the reports as part of the course they attended. Participants completed the cover page of the report containing personal information but they were informed that these details are used to create a demographic for the study only. When analysis of the resulting reports commences, each will be allocated a pseudonym with which all future analyses will be referenced. Participants will be told that their reports will be coded to ensure anonymity. The names and details of individual participants have not be used for analysis purposes. The names are only needed for identity when merged with the larger database for this study.

Each participant was given a consent sheet to complete before they completed the research report. They have been informed that their names will not be mentioned as part of the study. The reports will finally be kept in a safe place by the supervisor for three years and will then be destroyed. All documents, interview sheets and audiotapes will be kept in a safe place with the research supervisor to ensure that there is no unauthorised access to the information.

3.9. Conclusion

The data from pre-service teachers' research reports and exam equivalent were analysed to indicate the levels of TSPCK held by the pre-service teachers and determine congruency between their identification of TSPCK and that of a researcher with many years' teaching experience, and research experience in TSPCK. Analysis will show that TSPCK episodes identified in lesson plans experience authentic expansion into a cluster of episodes while maintaining the original intention of the lesson. The analysis of the pre-service teachers' views will give insight into their level of belief development toward a learner-centred teaching approach. Results will therefore attempt to determine whether pre-service teachers who are exposed to TSPCK intervention, are aware of their learning and the object of learning and which factors in their learning has helped them to develop.

Chapter 4: Analysis of pre-service teachers' TSPCK in their lesson planning and actual teaching

In this chapter, I will present the findings of my qualitative evaluation of pre-service teachers' analysis of their research reports, where they presented their analysis of their own classroom practice. The reports reflected on the quality of TSPCK in their planning and enacting of their own classroom teaching. The pre-service teachers' reports included TSPCK maps based on their lesson plans and the transcripts of the lessons they taught during their practical teaching experience. The findings will show how pre-service teachers identified evidence of the transformation of their content knowledge. Furthermore, show how authentic their identifications of TSPCK episodes are in relation to an operating definition of TSPCK, and whether there is agreement between their analyses and mine. In conclusion I summarise the findings in relation to the research question investigated.

4.1. Introduction

Final year physical science pre-service teachers' projects were part of a requirement in the chemistry methodology course. The project required them to plan for lessons in specific topics and then to teach them with audio/video recordings, and upon reflection of both, identify the TSPCK episodes present in lesson plans and those displayed in the lessons they taught. In brief, the method of analysis requires identification of teaching segments or extract of lessons plans that contain TSPCK episodes. These are then analysed by identifying components of TSPCK present and describing their interacting nature. TSPCK maps that correspond to the analysis are then drawn to pictorially present the identified TSPCK episode. Pre-service teachers then reported on their analysis and qualitative evaluations through research reports. In this chapter, I report on findings from examining and evaluating their analyses for emerging patterns, the authenticity and accuracy of their analyses and findings about the quality of their TSPCK. The evaluation of the pre-service teachers' analyses establishes a baseline for shared interpretations of data analysed by pre-service teachers and myself as a matured researcher, and therefore the extent of the authenticity of the patterns observed in this study as a whole.

The findings are with respect to the first research question on what patterns of TSPCK component interactions emerge from pre-service science teachers' analysis of their own planning and actual classroom teaching.

4.2. Analysis

The submitted research project reports were analysed by examining the extracts of lesson plans and teaching segments presented as containing TSPCK Episodes and the corresponding TSPCK maps drawn. The authenticity of their TSPCK episodes and component identification were determined by focusing on the extent of agreement that existed between the TSPCK episodes identified by the pre-service teachers and those I was able to identify using their descriptions/extracts. The TSPCK maps drawn by pre-service teachers for planning and actual classroom teaching were compared to the descriptions of lesson plans and transcripts of taught lessons. During analysis, episode identification was made in the written descriptions first and then matched to the TSPCK maps. I inserted descriptors with arrows pointing to the components for identification and correlation purposes. This assisted in ensuring that the components and episodes identified by the pre-service teachers were authentically depicted in the TSPCK maps they had drawn.

4.3. Findings

Analysis of the data revealed three key findings: Firstly, there were notably more TSPCK episodes in the pre-service teachers' analysis of actual teaching of the topics as compared to the episodes they identified in their planning, while the intentions of the lessons from the planning context is maintained and delivered in the actual classroom teaching, despite the difference in the quantity of TSPCK episodes. Secondly, there was an overwhelming agreement between their submitted analyses of TSPCK observed in their lesson plans and classroom practice with the analysis I did from the data they have used. Thirdly, TSPCK Episodes generated from specifically planned intentions could be vividly distinguishable in the classroom delivery as clusters of episodes. Evidence of the emergent patterns is first unpacked in the discussion below.

4.3.1. The comparison between TSPCK episodes in planning versus actual teaching.

A comparison was made of the analyses of the pre-service teachers regarding the number of TSPCK episodes identified in their lesson plans versus the TSPCK episodes identified in actual classroom teaching of those planned lessons. The analysis was based on lesson plans and observations of two lessons per participant. TSPCK episodes were analysed to determine the intention of the lessons by noting the components in the TSPCK episodes of the planned and enacted lessons in order to show whether there was an increase in the number of episodes in teaching versus planning. Any additional episodes were then analysed as per their component composition ratio to determine whether the lesson was merely expanded on and if the original intention of the lesson was maintained. TSPCK episodes were condensed to allow clear indication of the nature of the episodes in terms of integration of components, and when the components merely succeeded each other during the episodes. Upon matching transcripts and descriptions to the TSPCK maps, analysis was done on the extent to which the TSPCK maps represented the activities taking place in the classroom. The total sample of 23 participants were analysed. Table 4.1 presents the overview pattern.

Table 4.1. Table comparing the number of TSPCK episodes in planning vs. teaching.

Participant	**No of identified TSPCK Episodes in Planning**	**No of identified TSPCK Episodes in classroom**
Vuyo	1	5
Buhle *	6	12
Jesse	3	7
Tony	7	9
Sipho *	6	8
Philani	2	4
Zandi *	2	4
Jonah	3	4
Debra	3	4
Willy	1	2
Petrus	0	3
Nonhlanhla	0	2
Patience	0	4
Mpho	7	7
Tersia	2	2
Alex	3	3
Pulane	2	2
Joe	2	2
Jane *	8	6
Helen	3	2
Cindi	3	2
Jack	1	0
Elias	3	2

The table has two columns that display the amount of TSPCK episodes correctly identified by the pre-service teachers in the lesson plans and actual teaching and confirmed by the researcher. The participants set aside for in-depth analysis are indicated with an asterisk. From the table it can be seen that there were numerically more episodes in the actual teaching of the topic than in the planning for teaching. For some of the pre-service teachers, the number of episodes were listed as zero due to the fact that either I was unable to agree with the episodes at all, or that I was unable to verify the episodes due to the lack of transcripts in the reports submitted, as in the case of Nonhlanhla and Petrus. The effect is that is seems that there are in some participants less teaching episodes than planned episodes, but the table only indicates the number of episodes I was able to verify. In the reports themselves, there were more teaching episodes in general, but I did not include them in order to maintain the reliability of the episodes I do mention in this study. Due to the fact that, from the 23 participating pre-service teachers, 13 of the teachers clearly exhibited more teaching episodes than what they had indicated in their lesson plans. I decided to focus my in-depth study of their TSPCK maps on 4 teachers to illustrate best the display of the pattern showing expanded TSPCK episodes in classroom contexts.

A key finding was revealed in the comparison of the TSPCK maps of the lesson plans and the actual classroom teaching. TSPCK episodes displayed in lesson plans expanded into more episodes or more repetitions of components when acted out in actual classroom lessons. Single planned-for episodes blossomed into clusters of TSPCK episodes during teaching. Figure 4.1, of Zandi’s first lesson as illustrated below shows the mechanism of expansion of the episodes from planning to teaching, indicating the original episode from the planned episode as it plays out in the actual classroom teaching.

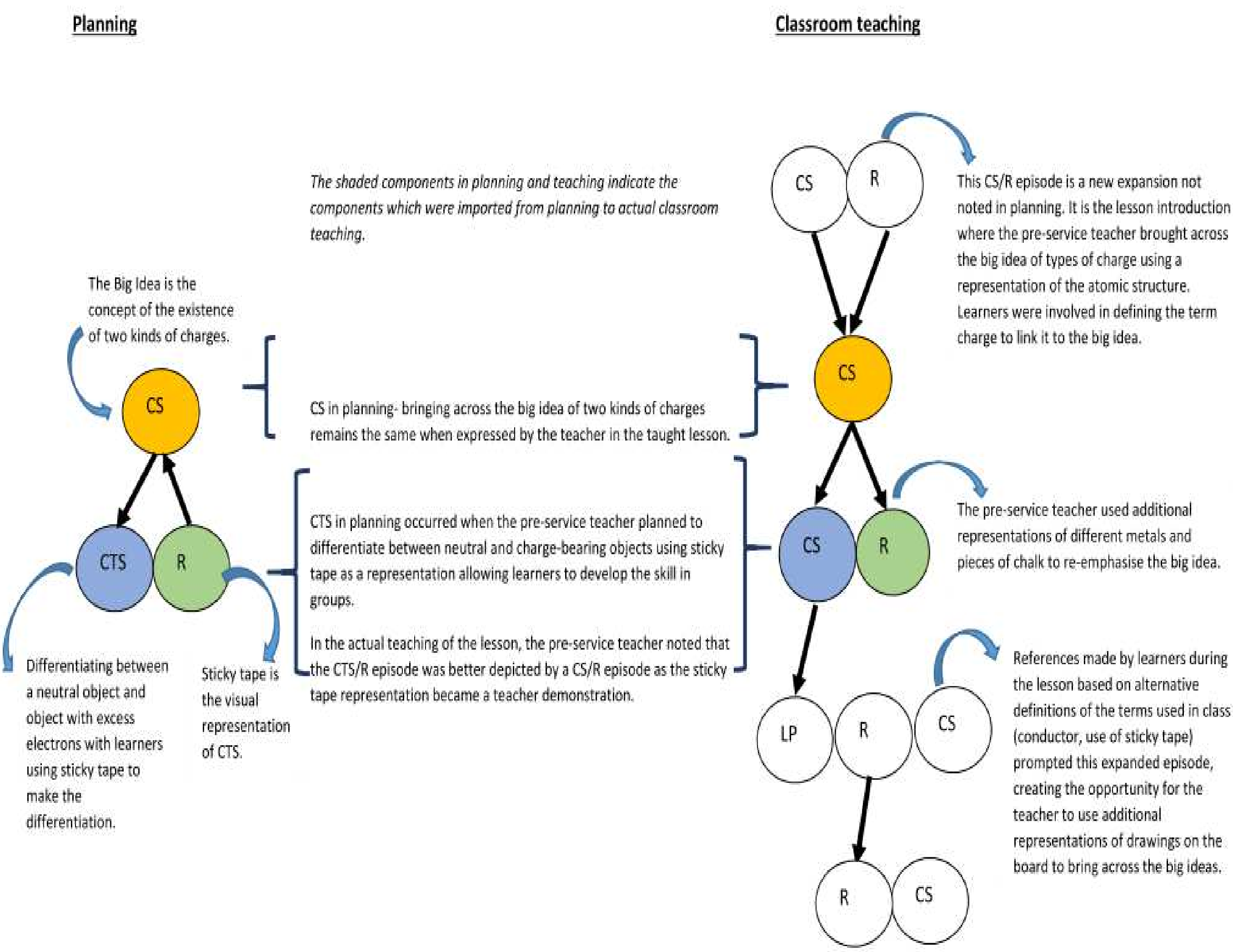


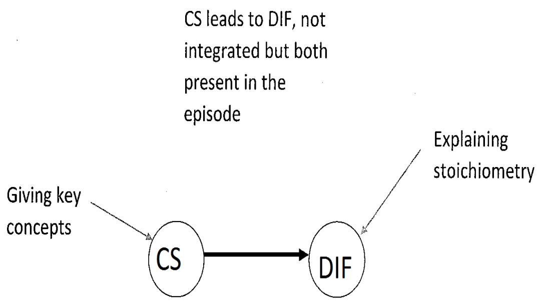
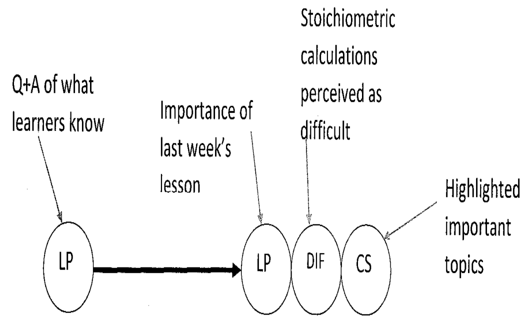
Figure 4.1. Zandi's first lesson showing the expansion of TSPCK episodes in classroom enactment.

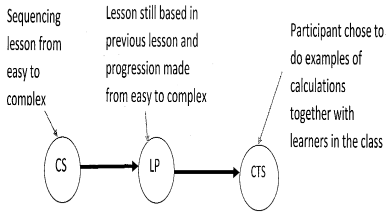
In the lesson plan as featured in the left hand side of Figure 4.1, the big idea (CS) brought across to the learners was about the existence of two kinds of charges. Zandi planned a to use a conceptual Teaching Strategy (CTS) to of comparing the two charges and differentiating between a neutral object, electron-deficient object and an electron-rich object. The CTS component integrated with the component of representations (R) as he planned to use sticky tape as part of his visual representation of attractive electrostatic forces.

The actual classroom teaching TSPCK episodes featured in the right hand side of Figure 4.1 expressed the same big idea,with the original planned TSPCK episode in colour to indicate where the episode exhibited itself in the actual delivery of the lesson.The sequencing of the lesson was expanded first reflecting awareness of the pre-service teacher of the need for discussing pre-concepts (structure of an atom) before discussing charges. The expansion is noticed again much further into the lesson with an additional TSPCK Episode LP/R/CS. This expansion occurred due to the verbal interactions the teacher had with the learners. The pre-service teacher seem to have noted that the learner prior knowledge (LP) was focussing on the everyday definitions of the terminology used. He acknowledged the importance of addressing learners' prior knowledge to prevent the formation of misconceptions. He then added more representations displaying different types of charges before summarising with equations representing the concepts. Figure 4.1 shows an expansion of the TSPCK episode, while still maintaining the essence of the planned lesson. Given below is a sample of extracts from lesson plan versus observations of the four teachers from which the TSPCK Episodes shown in Figure 4.1 were drawn. The episodes drawn by the pre-service teachers for their subsequent lessons can be found in appendix 2.

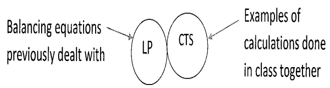
Table 4.2 Comparison of TSPCK episodes in planning and classroom teaching.

The episodes represented in the table were created by the pre-service teachers, authentication and descriptions on the TSPCK maps were done by myself to generate secondary data. The descriptions were taken from the lesson plans and classroom teaching transcripts, and inserted appropriately next to the TSPCK component it reflected. This made for easier understanding of the nature of the interacting components without having to keep referring to the original transcripts for clarity.

Jane	Stoichiometry Lesson Plan 1 Introduction  Body	Lesson1-stoichiometry  Body

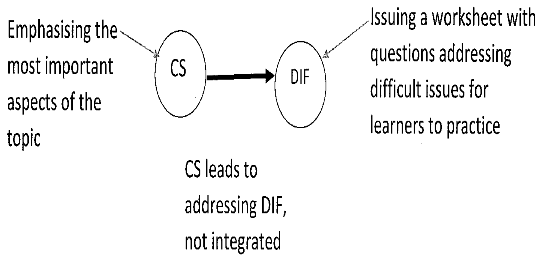


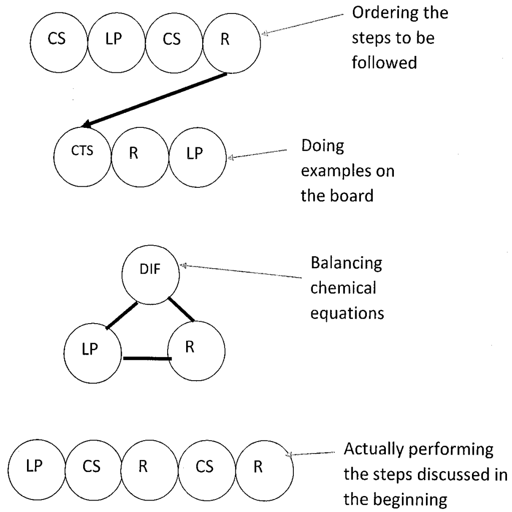
Episode 1



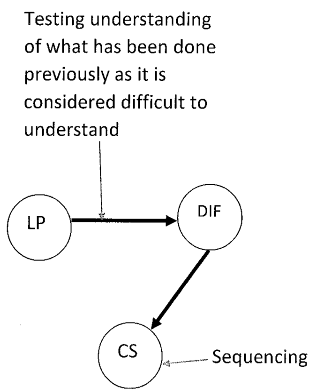
Episode 2

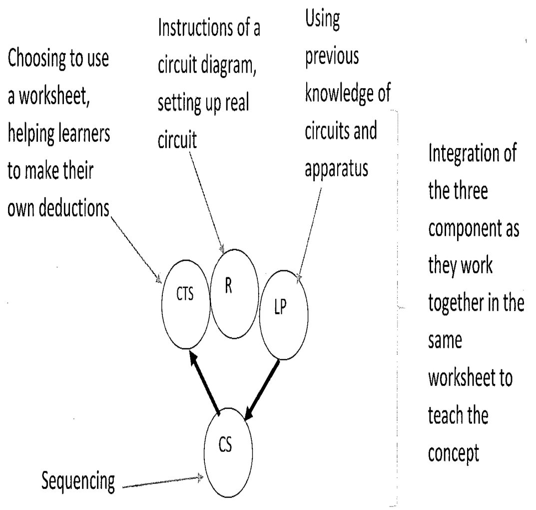
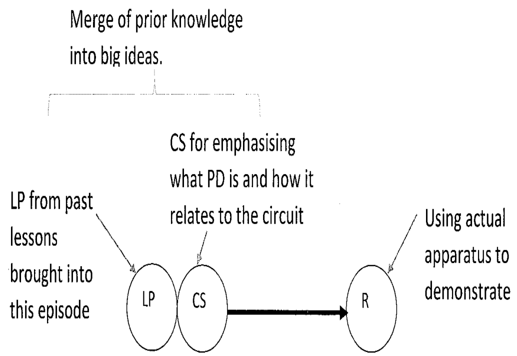
Conclusion

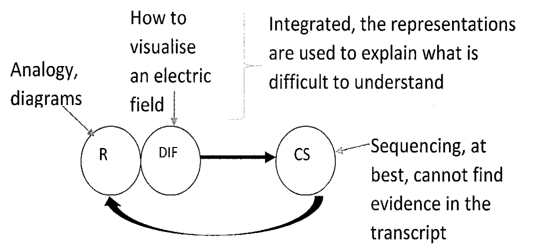


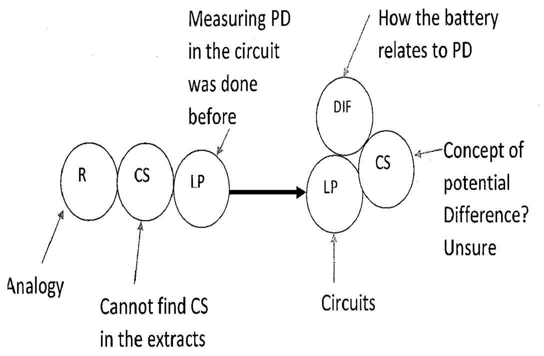


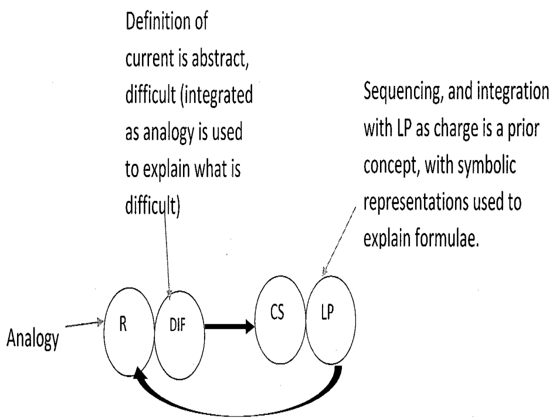
Conclusion

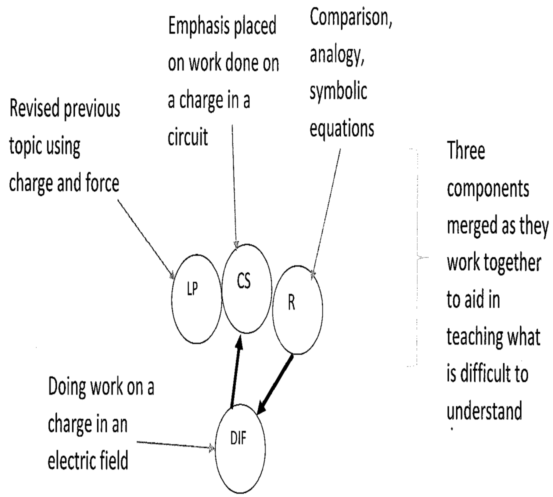


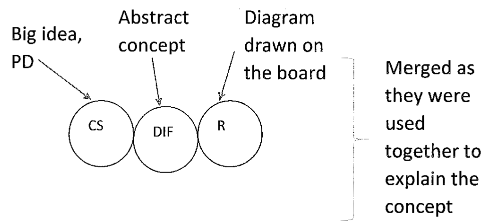
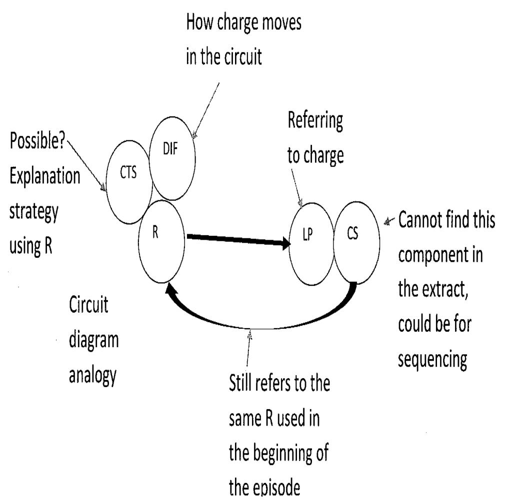
Buhle	Lesson 1 Potential Difference and current  	Lesson 1 Potential difference and current 


How to visualise an electric field
Analogy, diagrams
Integrated, the representations are used to explain what is difficult to understand
R
DIF
CS
Sequencing, at best, cannot find evidence in the transcript


Measuring PD in the circuit was done before
How the battery relates to PD
DIF
R
CS
LP
LP
CS
Concept of potential Difference? Unsure
Analogy
Cannot find CS in the extracts
Circuits

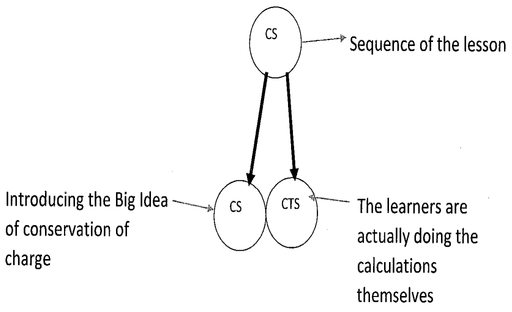

Definition of current is abstract, difficult (integrated as analogy is used to explain what is difficult)
Sequencing, and integration with LP as charge is a prior concept, with symbolic representations used to explain formulae.
Analogy
R
DIF
CS
LP

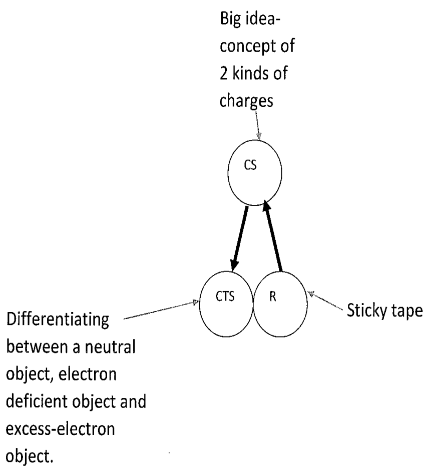

Emphasis placed on work done on a charge in a circuit
Comparison, analogy, symbolic equations
Revised previous topic using charge and force
Three components merged as they work together to aid in teaching what is difficult to understand
LP
CS
R
Doing work on a charge in an electric field
DIF

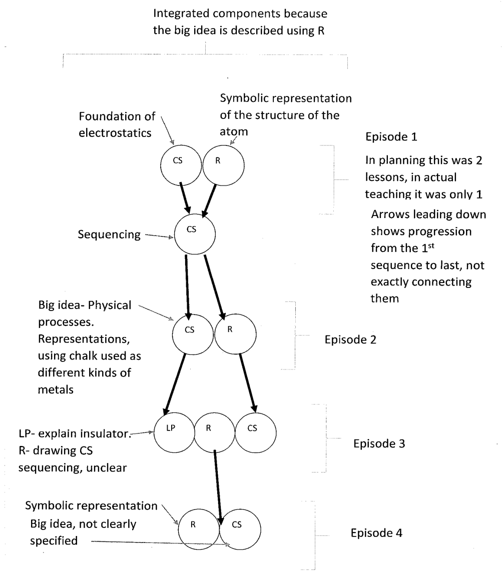
		Big idea, PD Abstract concept Diagram drawn on the board CS DIF R Merged as they were used together to explain the concept How charge moves in the circuit Possible? Explanation strategy using R CTS DIF R Referring to charge LP CS Cannot find this component in the extract, could be for sequencing Circuit diagram analogy Still refers to the same R used in the beginning of the episode

Zandi

Lesson 1
Two kinds of charges







There exists a clear trend that more TSPCK episodes are visible in the classroom enactment of the planned lesson as can be seen in Table 4.4 below. The reasoning behind the planned episodes appear expanded upon when enacted in an actual teaching situation with all the complexities found in the class.

4.3.2. Planned TSPCK episodes were expanded in actual classroom teaching

To elaborate on this finding, a table of TSPCK sequences is provided below. In the Table the pictorial TSPCK Maps shown in Table 4.3, each episode was represented as a sequence of components as depicted in the last two columns of Table 4.3 above, are shown as TSPCK sequences for simplification. A TSPCK sequence is a simplified representation of the TSPCK episode using a forward slash in the episode indicates integration between the listed components i.e R/DIF, and the dash indicates the order of the sequence i.e. LP-R as shown in Table 4.3 below.

Table 4.3. Number of episodes present in planning and teaching.

Participant	Lesson number	Number of episodes present in the lesson plan	Number of episodes present in the actual teaching segment	Components featured in the episodes for planning	Components featured in the episodes for actual teaching
Sipho	1	2	4	EPISODE 1	EPISODE 1
				LP-R/DIF/CTS	R/DIF
				EPISODE 2	EPISODE 2
				R/DIF-CS	R/DIF-CS
					EPISODE 3
					R/DIF/CS
					EPISODE 4
					LP/CS
	2	2	3	EPISODE 1	EPISODE 1
				LP-CS/R-LP/R	LP/CS-R
				EPISODE 2	EPISODE 2
				CS-R/CS	LP-CS
					EPISODE 3
					LP-CS-R
	3	2	1	EPISODE 1	EPISODE 1

Participant	Lesson number	Number of episodes present in the lesson plan	Number of episodes present in the actual teaching segment	Components featured in the episodes for planning	Components featured in the episodes for actual teaching
				LP-R/DIF	LP-LP-R/DIF
				EPISODE 2	
				R/CS	
	TOTAL	6	8		
Jane	1	4	2	EPISODE 1	EPISODE 1
				CS - DIF	LP-LP/DIF/CS
				EPISODE 2	Could not agree on the other episodes
				CS- LP-CTS	EPISODE 2
				EPISODE 3	LP-DIF-CS
				LP/CTS	
				EPISODE 4	
				CS-DIF	
	2	4	4	EPISODE 1	EPISODE 1
				CS/LP/CS	LP/CS/R
				EPISODE 2	EPISODE 2
				LP/CS/R	LP/DIF/CTS-CTS/CS
				EPISODE 3	EPISODE 3
				R-CS	CTS/CS/CTS/CS
				EPISODE 4	EPISODE 4
				DIF/CS	LP/CTS/DIF
	TOTAL	8	6		
Buhle	1	3	5	EPISODE 1	EPISODE 1
				CTS/R/LP-CS	LP/CS-R
				EPISODE 2	EPISODE 2
				R/DIF-CS	R/CS/LP-DIF/LP/CS
				EPISODE 3	EPISODE 3
				R/DIF-CS/LP	LP/CS/R-DIF
					EPISODE 4
					CS/DIF/R
					EPISODE 5
					CTS/DIF/R-LP/CS

Participant	Lesson number	Number of episodes present in the lesson plan	Number of episodes present in the actual teaching segment	Components featured in the episodes for planning	Components featured in the episodes for actual teaching
	2	2	2	EPISODE 1	EPISODE 1
				R/LP/CS	R/LP/CS/DIF/CTS
				EPISODE 2	EPISODE 2
				CTS/CS/LP-R	CS/DIF/LP-R
	3	1	5	EPISODE 1	EPISODE 1
				LP-CTS/CS-R	LP-DIF/CS/R
					EPISODE 2
					CS/DIF-LP/R
					EPISODE 3
					CS/R/DIF-LP
					EPISODE 4
					CS-LP/R
					EPISODE 5
					CS/LP/R
	TOTAL	6	12		
Zandi	1	1	4	EPISODE 1	EPISODE 1
				CS-CTS/R	CS/R-CS
					EPISODE 2
					CS/R
					EPISODE 3
					LP/R/CS
					EPISODE 4
					R/CS
	2	1	0	EPISODE 1	
				CS-CS/CTS	
	TOTAL	2	4		

The first column of the table contains the assumed names of the pre-service teachers. In the second column, the number of the two representative lessons are indicated. In the table it can be seen that there are more TSPCK episodes found in the actual teaching of the topic as seen in the last column than in the planning of the lesson. Lesson plans were described in a more packaged format according to generic lesson plans they were taught in their training classes but as they presented the lessons, they use TSPCK components in a more expanded way. In their lesson plans, their references to specific components, for example CS are during the teaching episode changed to R and CTS. Comparisons made between the planned and enacted episodes show that the component types used for the specific topics were maintained, indicating that the intention of the planned lesson was maintained, but there were more clusters of the component groupings to be found in actual classroom teaching, possibly due to the teacher interacting with the learners and associated complexities in the classroom in order to bring the topic across to the learners.

Participant Jane shows a smaller number of episodes than for planning, but actually did have more episodes, I did not include them in the analysis since I was unable to agree on the episode component description based on the lesson transcripts, and therefore still contribute to the trend in terms of frequency counts. The additional episodes found in the actual teaching segments indicate that the same components were used as in the planning of the lesson, in general, but that during the teaching of the concept, the pre-service teacher expanded the use of the components increasing the number of episodes, while maintaining the component theme of the lesson.

Upon comparison between the frequency of components used during planning and teaching, there is great similarity in the types of components used, indicating that, even though there were more teaching episodes present in the teaching sequences, they still focused on using the same components as were originally planned for.

Table 4.4. Frequency count of the components evident in the TSPCK episodes in planning and teaching.

Frequency count of components for planning versus teaching												
Participants		Components present in planning						Components present in teaching				
		LP	CS	DIF	R	CTS		LP	CS	DIF	R	CTS
Sipho		5	5	3	6	1		6	6	4	6	0
Jane		4	8	3	2	2		6	6	4	1	5
Buhle		5	6	2	6	3		12	13	9	12	2
Zandi		0	3	0	1	1		0	0	0	0	0
TOTAL		14	22	8	15	7		24	25	17	19	7
%		21	33	12	23	11		26	27	18	21	7.6
Ratio in which TSPCK components were used by pre-service teachers		1.91	3.00	1.09	2.09	1.00		3.42.	3.55	2.37	2.67	1.00

Table 4.4 shows the frequency of the appearance of each component in the analysed episodes. The headings differentiate between the five components in planning and the last columns, the components identified in the teaching TSPCK episodes. Totals were calculated for each of the components featured across the four pre-service teachers, and the totals were converted into percentages. The percentage frequency of the components identified were converted to ratios in order to facilitate a comparison between the frequency of component use in planning and teaching. The table ratios show that the most frequently used components were LP, CS and R, in order of frequency, which were also the combination of components found to feature prominently in similar research done by Mavhunga (2015). The components DIF and CTS featured the least in planning and teaching episodes. It is possible that pre-service teachers gain the skills to use the components LP, CS and R before the lesser used components and therefore feature a smaller number of DIF and CTS in their TSPCK maps.

It becomes clear to see that, although there were more teaching episodes, featuring more components, the ratios and order of frequency used remained constant, indicating that the taught lessons were expansions of the planned lessons, and the original intention of the lesson, the use of specific components, was maintained.

The TSPCK maps in table 4.2 point out what is happening in the lesson plans and in the classroom as the transcripts and explanations the participating pre-service teachers wrote to describe their episodes were used to design the labels for the maps. Using the arrows as a sequencing guide, it is possible to see the layout of the lesson based on the components used. Using one of the maps of Buhle, who was teaching the concept of potential difference and current, the map shows that the components LP and CS were integrated, using the learners' prior knowledge from previous lessons in order to emphasise what potential difference is and how it relates to the circuit. These two components were the foundation for the teacher to be able to use apparatus to perform a demonstration to explain potential difference in a meaningful manner, whereas it would have been difficult for learners to understand the demonstration if the prior knowledge was not linked to the current apparatus.

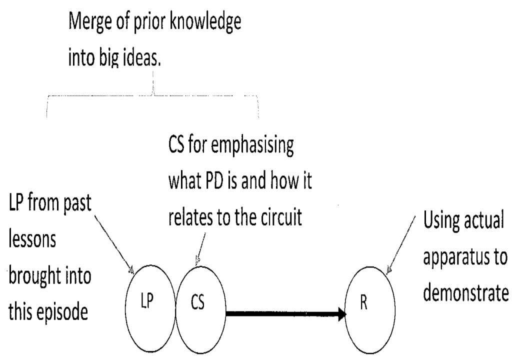


Figure 4.2. TSPCK map showing class activity from Buhle.

Of the episodes that are shown in table 4.2, the activities planned for and enacted in the classroom can be noted. A comparison of the planning and actual lesson reveal that the intention of the planned lesson was kept during the taught lesson, but expanded on the original episodes.

For example, the first lesson of Sipho as seen in Figure 4.3 contained two planned episodes where the pre-service teacher would teach the concept of limiting reactants by first recapping what learners already knew about stoichiometry by using a diagram of a difficult concept to assist learners to create their own understanding. Secondly the pre-service teacher planned to use an analogy to explain what was known to be a difficult section of limiting reactants.

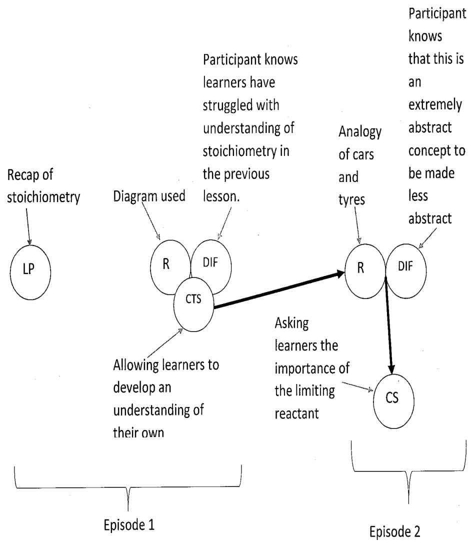
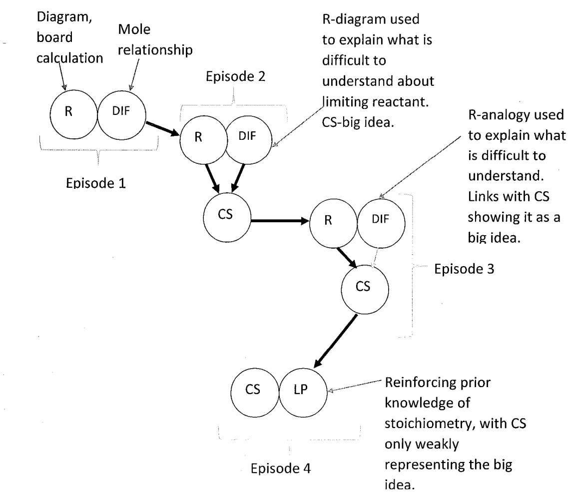
<table>
<tr>
<td>Sipho</td>
<td>Lesson 1
Limiting reactants

</td>
<td>Lesson 1
Limiting reactants

</td>
</tr>
</table>

Figure 4.3. TSPCK maps in planning and teaching of limiting reactants by Sipho.

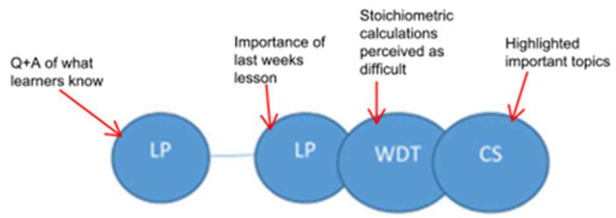
In the actual teaching of this lesson, 4 definite episodes were noted, where the pre-service teacher started the lesson by doing a calculation of a difficult section of stoichiometry. This episode is similar to the first planning episode as the planning episode didn't specify how the recap was done and could resemble what was actually done in teaching. The second and third teaching episodes resemble an expansion of the second planned episode. The pre-service teacher used a diagram to explain the difficult section of limiting reactant which was noted as the big idea, then moving through the lesson with an analogy that expands on the previous diagram with the same set of integrated components. The fourth episode showed more expansion of the original plan as it was meant to reinforce the big idea as well as the prior knowledge.

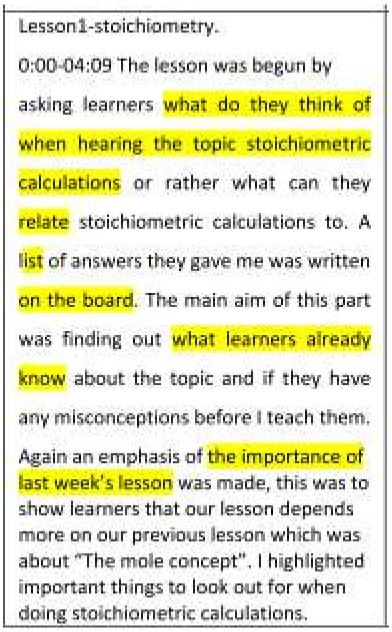
4.3.3 Authentication of pre-service teacher TSPCK map analyses

Pre-service teachers used in-depth qualitative analysis method to identify and describe TSPCK moments in their lessons. Teaching segments were identified in lesson plans and teaching transcripts and analysed to search for instances where TSPCK components appeared. The components were then listed, and placed in a sequence, or as an integration with other components. TSPCK maps were then constructed of these teaching instances and pre-service teachers provided their own analysis of the episodes. As a researcher, I followed the same analysis technique where I started with an identified teaching segment, identified a TSPCK episode, and then analysed the segment for the sequence, names of components present in the sequence and the way in which the components interact in the sequence. TSPCK maps were rated in terms of the agreement I had with their analysis of the segments. Good agreement is reached when I fully agree with the TSPCK episodes identified in a teaching segment as well as their analysis of the sequence in which the components appear, their names, and their interaction.

Park and Chen (2012) defined a TSPCK episode as a teaching segment wherein two or more TSPCK components interacted and the pre-service teachers used this definition in the analysis. They represented the transformation of content knowledge in their planning and teaching by drawing TSPCK maps, the graphical representation of the connections between the TSPCK components in a teaching episode (Park & Chen, 2012). It is important first to explain and show an example of a TSPCK map for clarity in the evidence presented below.

Below is an example of a TSPCK map. Circles with abbreviations are used to represent the TSPCK components present in a teaching segment. For example, Figure 4.2 presents a TSPCK episode made out of three TSPCK components. These are Learner Prior Knowledge (LP) repeating; What is difficult to understand (WDT) and Curricular saliency (CS). The circles are presented in the order in which the components are identified in a teaching segment. Thus the order presented in Figure 4.1 is the component of Leaner Prior Knowledge observed first, repeated in manner that drew on What was difficult to understand, followed by drawing on curricular saliency. The circles are presented in which they are observed interacting. For example, for the TSPCK episode presented in Figure 4.2, Learner Prior knowledge is first observed in the teaching segment as a clear stand-alone portion of what the teacher said. There is then evidence that the teacher moved to a discussion, that drew on learner prior knowledge (different to the first), What is difficult and curricular saliency in manner that is in that order but inseparable.




Lesson1-stoichiometry.

0:00-04:09 The lesson was begun by asking learners what do they think of when hearing the topic stoichiometric calculations or rather what can they relate stoichiometric calculations to. A list of answers they gave me was written on the board. The main aim of this part was finding out what learners already know about the topic and if they have any misconceptions before I teach them. Again an emphasis of the importance of last week's lesson was made, this was to show learners that our lesson depends more on our previous lesson which was about "The mole concept". I highlighted important things to look out for when doing stoichiometric calculations.

Figure 4.4. Example of a TSPCK map with accompanying classroom teaching transcript

The TSPCK maps constructed by the pre-service teachers display the sequence in which the components appeared in the teaching plans or transcripts of teaching events and the actual components featuring in the teaching episode used to bring across meaning to the learners and the linked components indicate their integration in teaching the lesson. In this way, the type of components used, the sequence and methodology of the lesson can be viewed at a glance.

I used three categories to classify the agreement, namely, good agreement, moderate agreement and poor agreement. Table 4.5 below presents the extent of agreement across the entire sample. Pre-service teachers set aside for the detailed study are indicated with an asterisk.

Table 4.5. Overview of the agreement of analyses for TSPCK episodes in planning and classroom teaching

Pre-service teacher	**Lesson planning**		**Classroom teaching**		**Verdict**
Column	1	2	3	4	5
	Episodes identified by pre-service teachers	Episodes identified by researcher	Episodes identified by pre-service teachers	Episodes identified by researcher	
Sipho *	6	6	8	8	Good agreement
Pulane	2	2	2	2	Good agreement
Jane *	8	8	11	11	Good agreement
Joe	2	2	2	2	Good agreement
Alex	3	3	3	3	Good agreement
Buhle *	6	6	12	12	Good Agreement
Willy	1	1	2	2	Good agreement
Philani	2	2	4	4	Good agreement
Mpho	7	7	6	6	Good agreement
Zandi *	3	3	4	4	Good agreement
Debra	2	2	4	4	Good agreement

Pre-service teacher	Lesson planning		Classroom teaching		Verdict
Column	1	2	3	4	5
	Episodes identified by pre-service teachers	Episodes identified by researcher	Episodes identified by pre-service teachers	Episodes identified by researcher	
Helen	3	3	3	2	Good agreement
Elias	3	1	3	3	Moderate agreement
Jesse	3	3	9	6	Moderate agreement
Masego	4	3	3	2	Moderate agreement
Vuyo	1	1	5	4	Moderate agreement
Jack	5	3	6	3	Moderate agreement
Thapelo	3	1	3	1	Moderate agreement
Patience	1	0	4	4	Moderate agreement
Jonah	11	3	16	4	Poor agreement
Nonhlanhla	0	0	3	1	Poor agreement
Tony	7	7	9	-	Poor agreement, no transcripts to make confirmation
Petrus	-	-	3	3	Poor agreement, no transcripts to make confirmation

Table 4.5 indicates a good agreement for 12 of the participants and moderate agreement for 7 participants across all the analysis conducted, on extracts from lesson plans as shown in columns 1 and 2. The same pattern is observed for extracts of teaching segments as shown in columns 3 and 4. From the table the number of episodes identified by the pre-service teacher can be seen. In instances where I was able to find sufficient evidence in their transcripts and descriptions, the verdict of good agreement between the pre-service teacher and myself was given. Following below are examples of the actual analysis depicting good agreement. The figure below is an example of good agreement from the TSPCK map constructed by Buhle.

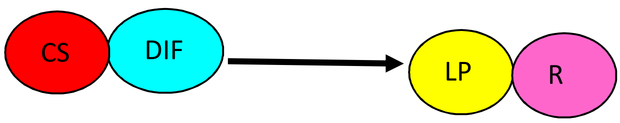
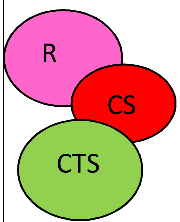
Description	**Extract from transcript of classroom lesson**	**Pre-service teacher's TSPCK map representing the transcript extract**	**Researchers analysis for authentication of TSPCK map drawn by pre-service teacher according to transcript extract**
Teaching segment extract from Buhle's lesson Lesson 3 (Topic): Resistance Episode 2 *Buhle was teaching Current electricity and the resistance in a circuit- then noted (as confirmed in her notes) they did not understand the concept of EMF, which is a key concept (CS)*	Extract of the transcript of the second episode (7th minute) of the lesson **Teacher**: "...as the electrons move in the conductor, a wire, they are not that free to move, why are they not that free to move[?], what makes up the wire? **Learners**: the wire is made up of the copper **Teacher**: let's say copper atoms and an atom is made up of protons and electrons and the electrons are the ones which are free to move remember we talked about this. The electromotive force is what causes the electrons to move. When there are [o]pposite charges what happens? **Learners:** they attract each other. **Teacher:** so we have electrons moving in the conductor but since there are positive ions the electrons are not that free to move [electrons bump on atoms that are tightly packed in solid wire] and this is what causes the resistance in the wire. In the Small street that we talked about [the teacher has drawn the electrons in the wire and keeps referring to it and making reference to Small street in Park-station]	TSPCK map drawn by Buhle dipicting TSPCK episode in her teaching segmentextract 	Agree **CS** is exhibited in the atomic description, an important concept needed before establishing resistance. **DIF**:The concept of EMF i difficult to understand. LP:opposite charges confirm previous understanding. **CS:** emphasis of what is important or needed for understanding, moving electrons. **Representation**: macro-representation of Small Street in Park station which is always congested with people bumping each other.

Figure 4.5. Buhle's analysis of TSPCK episode in a lesson on resistance.

The figure above is an analysis of the TSPCK map constructed by Buhle. The first column sets the context in which the episode was identified. The second column contains the extract from the transcript of the teaching segment that Buhle used to identify components for the construction of the TSPCK map. The third column contains the TSPCK map Buhle constructed from the extract. The final column contains my analysis of the first three columns, indicating that I agreed with the analysis, and the reasons for my decision. Buhle identified the use of CS from the big idea being taught, exhibited in her description of the atom, an important concept needed before establishing resistance, appearing in the lesson as follows: Teacher:"Let's say copper atoms, and an atom is made up of protons and electrons and the electrons are the ones which are free to move." CS was interacting with what is difficult to understand about EMF by mentioning to the learners that "the electromotive force is what causes the electrons to move". The use of these interacting components inform the subsequent use of the components Learner prior knowledge of electricity and circuits, representing the difficult concepts as macro-representations of an example of the people pushed together at Park station. I was able to identify the same components from the sequence, therefore I listed this episode as good agreement. Another example showing agreement between the pre-service analysis and mine is that of Vuyo, featured in Figure 4.6 below.

Description	**Extract from transcript of classroom lesson**	**Pre-service teacher's TSPCK map representing the transcript extract**	**Researchers analysis for authentication of TSPCK map drawn by pre-service teacher according to transcript extract**
Lesson 1 (Topic): Transverse pulses Vuyo was explaining the movement of a pulse though a medium.	I then did a demonstration – macroscopic representation (R): I took a duster and gave it to the first learner in front and asked her to pass it to the learner next to her. Teacher: Say for example, I have a pulse here… this is a pulse… pass it, pass it, no don't look at it, just pass it… pass it… pass it… pass it… pass it… pass it… pass it… that's a pulse it's moving. Learners: Oh Teacher: You can see the pulse started here and comes back. Therefore, the medium did not travel with the pulse, but moved the pulse. You did not move did you? Learners: No This Curricular saliency (CS) was displayed between 11:05min and 11:20min. Teacher: a transverse pulse is the pulse where all particles of medium disturbed move perpendicular or right angle to the direction in which the pulse is moving. I then drew a diagram – visual representation (RP) – on the chalkboard to show the shape of the transverse pulse. The intention was to show learners the		Agree, episode visible Several representations were used the macroscopic representation of passing the duster from the front to the back of the class, representing the pulse movement, learners as the medium, later in the lesson the pulse was represented as a drawing on the board., the teaching strategy involving learner participation enhanced the representations, curricular saliency emphasises that it is important to remember that the medium does

	direction of movement of particles and that of the pulse. Teacher: The pulse is moving this way, the particles of the medium would be moving up and down (11:20min – 11:40min).		not travel with the pulse.

Figure 4.6. Vuyo's analysis of TSPCK episode in a lesson on pulses.

Vuyo drew an authentic TSPCK map representing the TSPCK episode which occurred in the classroom lesson on pulses. He effectively used different representations including a board duster and a diagram on the board to represent the pulse in a medium. The teaching strategy integrated with the representation as Vuyo used all the learners in the class to represent the medium through which the pulse moved. Curricular saliency was exhibited in Vuyo's reinforcement of the fact that it is the pulse, and not the medium which moves, an important concept in pulse propagation.

The last example showing agreement between the pre-service teacher's analysis and mine is that of the lesson plan of Pulane in Figure 4.7 below.

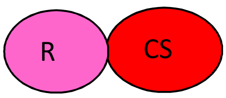
Description	**Extract from transcript of classroom lesson**	**Pre-service teacher's TSPCK map representing the lesson plan extract**	**Researchers analysis for authentication of TSPCK map drawn by pre-service teacher according to transcript extract**
Extract from Pulane's lesson plan Lesson 1 (Topic): Physical and Chemical change	Extract of the lesson plan. Learners have to work collaboratively in the form of a class discussion. This unit was based on the introduction of what physical and chemical changes are. After the introduction. Explanation segment, I [would] use a teaching aid (an overhead and display[s] the experiment on a transparency) to show learners kinds of experiments that new products are formed. And also experiments where substances undergo a physical change, their properties and examples to tell if there is a physical or chemical change taking place	TSPCK map drawn by Pulane dipicting TSPCK episode in her lesson plan segmentextract 	Agree **CS** is exhibited in the important concept of knowing the difference between physical and chemical change. **Representation:** teaching displays of symbolic representations showing chemical changes, product formation versus physical change.

Figure 4.7. Extract from the lesson plan of Pulane.

The lesson-plan of Pulane, as shown in Figure 4.7 indicates the integration of the two TSPCK components of Curricular saliency and representations. There is an important foundational chemistry concept to be taught (physical and chemical change) and the difference between them is taught through the use of various representations to show the differences between the two parts of the concept, hence the integration of the components.

In summary, the examples shown above indicate the nature of presented analysis of lesson plans and teaching classroom which I have been in agreement with. The level of agreement between myself and the pre-service teachers were the same for their lesson plans as actual classroom teaching transcripts. As mentioned, establishing this agreement was important in determining the authenticity of the patterns.

4.4. Conclusion

Analysis of pre-service teachers' TSPCK maps in lesson planning and actual classroom teaching illuminated several patterns in comparison. The episodes showed expansion in quantity of episodes in the teaching of planned topics, but the intention of the lesson was maintained in a large quantity of the participating pre-service teachers. The episodes, once verified to be authentic showed that the ratios of components were maintained, with curricular saliency, representations and learner prior knowledge being the most frequently used components in planning and actual classroom teaching. These findings could inform teacher education programmes of pre-service teacher's needs in development at this stage of their training, together with their views on teaching science, which will be discussed further in chapter 5.

Chapter 5: The Views Held by Pre-service Teachers About Using TSPCK in Their Teaching

In the previous chapter, I presented findings with regard to the first research question on the authenticity of pre-service teacher's analysis of the quality of TSPCK in their own teaching practice and the trends that emerged from such analysis. This was found to be authentic. In this chapter I present findings on the views they held about using TSPCK framework in their teaching. Pre-service teachers' views were grouped according to similarities in expression and emerging trends. These are discussed in detail. I close the chapter by summarizing the key findings.

5.1. Introduction

In this chapter I sought to answer the second research question of the study, which is, "What views do pre-service teachers hold about using TSPCK in their teaching?" The expressed views were analysed from direct and open ended questions asked across two sets of data. The first was the mini-research reports from pre-service teachers and the second the examination equivalent tasks submitted 3 weeks later.

In the mini-research project, there was an open-ended question seeking reflections on using the TSPCK framework in their planning and actual classroom teaching. Pre-service teachers responded to this question in writing. In the Exam Equivalent Task, pre-service teachers were asked the similar question and in addition specific, structured questions eliciting their beliefs about teaching science. As these views were asked in an exam setting, they were issued with a set of criteria emphasising that the marks were weighted in the reasons they provided for their views, as there was no single correct or incorrect answer. The analysis of their responses for the open ended questions both in the mini research reports and the exam equivalent was done through content analysis. On the other hand, the analysis of the responses from the structured questions on teacher beliefs were analysed using a rubric called Belief Maps adapted from Luft and Roehrig (2007), with pre-service teachers' beliefs equated with views as discussed in the methodology chapter.

Both these data sets were analysed for patterns of common beliefs emerging from the group. Together, the data from these two sources reveal what pre-service teachers regard as good science teaching. The analysis was able to broadly indicate where they fit in at this stage of their teacher development. They further described their views of the impact of the TSPCK development intervention and its contribution in their study journey towards becoming effective science teachers.

There are four key findings emerging from the analysis. First, pre-service teachers showed evidence of recognising that the teaching of science requires transformation of content knowledge. Second, pre-service teachers expressed positive views about the value of the TSPCK framework in in equipping them for entering the teaching profession. Third, advocated for the inclusion of the TSPCK framework in teacher preparation programmes. Finally, they portrayed evidence of being aware of the level of their teacher development and areas for improvement which they need to improve in order to be more effective teachers. These findings are presented one at a time with evidence below.

5.2. Recognition of teaching science requiring transformation of content knowledge.

Part of the aim of exposing the pre-service teachers to the TSPCK framework was to develop the understanding that teaching science requires transformation of content knowledge. According to Geddis and Wood (1997), this recognition is important in the PCK development trajectory. In this study, a question soliciting views of pre-service teachers was asked as part of developing a sense of the views held by pre-service teachers. Pre-service teachers were asked in their methodology examination question: “What does teaching science mean to you?” Analysis of their answers was performed by searching the pre-service teachers’ answers for the explicit awareness that teaching science requires a transformation of content revealed a positive trend. 16 of the 23 pre-service teachers, shown in Figure 5.1 below, explicitly mention the need for transformation of content in order to effectively teach sciences as an answer.

In the second set of data, which is their mini-research reports, there was also repeated explicit mention of this realization by 20 pre-service teachers reinforcing their expressed views. Only four pre-service teachers did not allude to the transformation of content in their exam question, they only mentioned it in their reflective paragraphs in the mini-research report. Table 5.1

below presents extracts from both data sets where explicit mentioning for the need to transform content knowledge is made.

Table 5.1: Sample extracts from the mini-research report and examinations indicating their views that science teaching requires transformation of knowledge.

Teacher	Extract from mini research reports	Extract from examination
Vuyo	I have learnt that using TSPCK components in the planning and actual teaching of lesson helps not only the pre-service teachers but also the experienced teachers to transform content knowledge to learners' understanding.	Teaching science to me means transforming content knowledge to learners' better understanding.
Helen	They [teachers] have to transform their CK and this transformation is known as PCK and they have to apply what they know to a specific topic that they are going to teach because PCK is topic specific in nature.	So teaching science to me is explaining to the students scientific phenomen[a] and everyday phenomen[a] in a way that they can relate and understand.
Patience	It has been realized that teachers need special understanding to teach such a topic like this effectively. In this case, the Topic Specific Pedagogical Content Knowledge (TSPCK) has been found out to be suitable in transforming concepts in a topic.	My role is to create an environment where I work together with the learner to transform the content knowledge I possess into forms the learners could understand.
Elias	This is because as a pre-service teacher, I realise that such a topic is somehow abstract in nature. This creates a problem for me to devise a sound methodology that can allow me to teach for understanding without promoting algorithmic approach.	This is because the teacher has specialised knowledge (PCK) that he can use to bring transformation of content knowledge.
Joe	Teachers should understand what they teach and understand it in several ways. The solution lies in the intersection of content and pedagogy and content, in the ability of a teacher to transform the content he or she has into forms that are pedagogically powerful and relevant to a certain grade.	…it means being able to transform science concepts.
Alex	From this I realized and learnt that the cognitive development of learners in each and every subject depends on the way teachers deliver the content to the learners and also their attitude towards that content. As teachers we must make sure that we thoroughly understand the concepts we are about to teach, and we are able to use various method in order to help learners understand the content of the lesson.	Teaching science means to transform the knowledge of science into a level which can be well understood by the learners so that they can be able to apply it in their occupations.

Table 5.1 reflects a common sentiment, expressed in different ways but nonetheless explicit about an understanding that teaching science requires a transformation of content knowledge. The quotes shown above present a sense that at the end of the methodology course, the pre-service teachers had explicit recognition of the understanding that science teaching requires

transformation of content knowledge. This emerging trend was found to be true among 87% of the pre-service teachers, when considering both their mini-research reports and examination.

5.3. Views about the value of using the TSPCK framework in teaching science

Pre-service teachers responded to the open-ended question in their mini-research reports about their views with respect to the use of the TSPCK framework in their lesson planning as well as in actual classroom teaching. Their responses were analysed thematically for emerging themes, tabulated in Table 5.2 below.

Table 5.2: Table of the common, emerging views held by the pre-service teachers, regarding the value of using the TSPCK framework in teaching science, N = 23.

Themes of views expressed	**Frequencies**	**Total**
1. Teacher education programmes incorporating TSPCK will assist pre-service teachers to become more effective teachers.	✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓	19
2. There were more TSPCK components and episodes noted in the teaching of topics than in the planning of the same topics.	✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓	18
3. The use of TSPCK components promote better knowledge transformation.	✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓	16
4. Using TSPCK components to plan and teach topics creates in teachers a better awareness, enabling better understanding in the learners.	✓✓✓✓✓✓✓✓✓✓✓✓✓✓	14

Table 5.2 listed the common views expressed by pre-service teachers expressed in their answers to the open question in the mini-research report. The first column indicates the most frequently mentioned themes that emerged from their responses. These themes we derived from analysis of the response to the single question of the whole sample by two raters who came to these themes by discussion until consensus was reached. As noted by the number of the ticks per theme in each row, it can be seen that there is a view shared by the majority pre-service teachers acknowledging usefulness of the TSPCK framework in planning and in actual classroom delivery of lessons.

In Table 5.3 below, examples of extracts of responses from pre-service teachers' views from their mini-research reports and examination are shown to further elaborate on the views about science teaching according to the themes which emerged during data analysis.

Table 5.3: Examples of extracts from pre-service teachers' views from their mini-research reports and examinations.

Teacher	**Examples of views expressed regarding theme 1:** ***Teacher education programmes incorporating TSPCK assist pre-service teachers to become more effective teachers***
Jonah	It is an important reasoning that all teachers ought to have before (and during) the transformation of any topic. Hence, TSPCK should be taught thoroughly, to all pre-service science teachers.
Nonhlanhla	Science teachers should be able to track their own development of PCK and identify elements of PCK in their own teaching. This will enable further research to see where there are loopholes and non-loopholes so that science education programs can change their curriculum and make other changes where needed. The framework will guide future preparation of science education programs.
Sipho	Teacher development programmes can be enhanced by encouraging pre-service teachers to develop reasoning for the interaction of TSPCK components in teaching episodes, and encouraging pre-service teachers, through TE to develop their own TSPCK episodes.
Buhle	Teacher education programmes where Content and methodology are taught together assist pre-service teachers in becoming more effective teachers. Using the TSPCK framework will assist beginner teachers to teach known topics and others they had not dealt with before.
Teacher	**Examples of views expressed regarding theme 2:** ***There were more TSPCK episodes found in actual classroom teaching as compared to the planning of the lesson***
Buhle	The most important aspect is that the episodes in the planned lesson occurred to be very little as compared to those in the actually delivered lesson
Jane	TSPCK episodes do not manifest in the same way in planning as in teaching episodes. There were more TSPCK components and episodes in actual teaching than were initially visible during the planning of the lesson.
Zandi	I saw more TSPCK episodes during teaching than I had written in the planning.
Teacher	**Examples of views expressed regarding theme 3:** ***TSPCK framework use promotes better knowledge transformation.***
Sipho	As time passed, I came to a new and deeper understanding of TSPCK. By reflecting on my lesson taught on TE, it allowed me to identify the problems

	in my teaching. With my new and deeper understanding of TSPCK I am able to develop lessons that promote conceptual transformation of the content.
Jane	The use of TSPCK components make my suggested lesson plan a good example of a lesson with transformed content knowledge. The lesson is not teacher centred, it involves learners and their prior knowledge.
Zandi	TSPCK components are not mainly the content that we teach and expect learners to understand after the lesson delivery. They are component that could be used to assist, to enhance learner understanding the usage of the components require us to know which ways that could help learners acquire knowledge and have less misconceptions which may arise during the lesson.
Teacher	**Examples of views expressed regarding theme 4:** ***Using the TSPCK framework creates better teacher awareness and learner understanding.***
Jack	This was indeed a learning opportunity to become more aware of my own teaching and to reflect on my own professional growth in order to improve my further development.
Jane	The use of TSPCK components during planning and teaching promote better transformation of content knowledge.
Buhle	The more component integration occurred in a lesson, the higher the quality of the lesson delivered. Using TSPCK as a framework, it makes lesson planning and teaching more effective.
Zandi	Consideration of the TSPCK components during planning and teaching enables teachers to enhance learner understanding.

While Table 5.3 displayed views that could be allocated to the emerging common themes, pre-service teachers also expressed views which were unique and relevant. For example, Sipho in addition to his views shown above, he also noted that CTS was the least used component in his planning and teaching of his topics. This observation, of the component of CTS and that of DIF being less used, was also clearly noted by myself when analysing their reports.

Overall, there was generally a positive attitude exhibited by the pre-service teachers concerning the implementation of TSPCK components in planning and teaching as none of the participants noted negative aspects regarding the experiences in their Teaching Experiences. All pre-service teachers indicated that they had an awareness of the use of the components in their planning and teaching once they analysed their work for the research project. Also, that there was a transformation in the content they taught which they felt would promote learner understanding. The pre-service teachers noted in their views that teacher education programmes using the TSPCK framework, would help develop teachers with a better understanding to transform content knowledge. As mentioned by Sipho, Buhle and Jane, they felt that their exposure to TSPCK as a pre-service teacher, would assist them in becoming more effective teachers in the future.

5.4. Pre-service teachers' awareness of their level of development as teachers

5.4.1. Empirical evidence of the level of development of the pre-service teachers

The Methodology course exam contained a section of structured questions with 7 items, each probing the pre-service teacher for their beliefs about teaching science and analysed according to the rubric adapted from Luft & Roehrig (2007), discussed in the Methodology Chapter.

Pre-service teachers were asked to answer the following questions concerning their personal beliefs about teaching science:

1. How can you increase chances for student learning in your science classroom?
2. Describe how you perceive your role as a science teacher?
3. During your school teaching experience, how did you know when your students understood what you taught them?
4. In a school setting, how do you decide what to teach and what not to teach?
5. How do you decide when to move on to a new topic in your classroom?
6. How do your students learn science best?
7. How do you know when learning is occurring in your science classroom?

The answers to the questions were rated according to Beliefs Rubric of teacher science belief coding adapted from Luft & Roehrig (2007). An extract of the rubric can be seen in Figure 5.1 below, with the complete rubric found in the appendix 2.

1. How can you increase chances for student learning in your science classroom?					
Teacher focused		Student focused			
Traditional Teacher provides information in a structured environment.	**Instructive** Teacher monitors student actions during teaching	**Transitional** Teacher creates a classroom environment that involves the student		**Responsive** Teacher designs the classroom environment to enable students to interact with each other and their knowledge.	**Reform-based** Teacher depends upon student responses to design an environment open to individualised learning
• "By carefully planning my lessons" • "By using PowerPoint presentations" • "By arranging the classroom so that the students face me" • "I use a textbook, a study guide and we have it on the web"	• "By looking at students' responses" • "I watch my students closely as they complete lab activities"	**Cognitive** • "By using different types of activities" • "By encouraging them to do their own thinking"	**Affective** • "By building a positive, supportive environment" • "By having a relationship with students outside of class"	• "By using small group activities in which students hypothesise, predict, create, share and question" • "By giving students the opportunities to defend their ideas in front of their peers"	• "Knowing that not all students learn in the same way, I need to organise the lesson in different ways" • "By allowing students to choose their own vehicles to learn by"

Figure 5.1: Extract from the Beliefs Rubric showing teacher- to student-focussed types of categories of teacher beliefs

For the seven questions, pre-service teachers' responses could be classified according to the type of teaching views they held, ranging from traditional beliefs, which fall in the teacher-centred category, to reformed beliefs denoting a learner-centred reform-based teaching approach. Transitional teacher beliefs are regarded as middle positioned beliefs, higher than traditional on the scale towards reformed kinds of beliefs.

The responses of pre-service teachers were scored by two raters according to the rubric, then presented for each pre-se-service teacher as their science teacher beliefs profile shown in Table 5.4.

Table 5.4: The science teacher beliefs profiles of pre-service teachers, N = 23.

Pre-service teacher	**Traditional**	**Instructive**	**Transitional**	**Responsive**	**Reform-based**
Willy			xxxx	x	xx
Sipho (did not answer all questions)	x	x			
Pulane	xxx		xxxx		
Joe	xxx	x	xx	x	

Pre-service teacher	Traditional	Instructive	Transitional	Responsive	Reform-based
Alex	x		xxxxx	x	
Helen	x	xx	x	xx	x
Jane	x	xxx	xx	x	
Philani			xxxx	xxx	
Mpho		xx	xxxxx		
Nonhlanhla			xxxxxx	x	
Debra	xx	xxx	xx		
Buhle		xx	xxxxx		
Elias	xx	xxx	xx		
Jesse	xx	xxx	xx		
Masego	xx	x	xxxx		
Vuyo		x	xxxxx	x	
Jack		x	xxx	x	xx
Thapelo	x	xxx	xx	x	
Patience			xxxxx	x	x
Jonah		x		xxxxx	x
Zandi	xx	x	xxxx		
Tony	x	x	xxx	x	x
Petrus	xx	xx	xx	x	
Totals	**24**	**31**	**72**	**20**	**9**

Table 5.4 indicates frequency of responses that were found to fall under a particular category. These are represented as crosses (x). The levels of teaching approaches range from what could be considered more basic, traditional, teacher-centred approaches to advanced, reform-based approaches.

The frequency totals in the last row of the table indicate the general pattern per categories in which the pre-service teachers tend to hold views about teaching. In the Transitional category column, there is a frequency of 72 responses followed by the instructive category with 32 responses. Both these categories fall in the middle of the scale, moving away from the traditional teacher beliefs towards the direction of reformed teacher beliefs. Column 2 shows that there are 24 responses made by the pre-service teachers which fall into the category of traditional views of teaching. 31 Responses featured as instructive, 72 responses were noted in the transitional category of teaching approaches. Responsive teaching approaches registered 20 responses and the reform-based approach to teaching were listed 9 times in pre-service teacher responses.

It can clearly be seen that the majority of the responses fall into the category of the transitional teaching approach. The transitional category of beliefs denotes a shift in beliefs towards a more student-focussed method of teaching. Value is given to student/teacher relationships and student understanding, with the teacher making decisions in the class based on student feedback. There is still a dependence on procedures and guidelines, indicating that, although there is a move away from the traditional category of beliefs, the views have not yet fully evolved to reforms-based beliefs.

5.4.2 Pre-service teacher awareness of their current levels of teaching approaches

One of the emerging views from pre-service teachers' mini-research reports was that they were aware of the category of their beliefs and teaching approaches. In their discussions they were able to note that there were areas they noticed were less developed than the abilities of more experienced teachers, and signalled unhappiness. In Table 5.5 below, the quotes from the pre-service teachers indicating their views about their level of development as pre-service science teachers.

Table 5.5: Overview of themes expressed by pre-service teachers as areas of concern

Themes of views expressed	**Frequencies**	**Total**
1. There is an awareness by pre-service teachers of a lack in development of their current abilities to use TSPCK components more fully and in depth in comparison to experienced teachers	✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓✓	16
2. CTS and DIF were the least used components in pre-service teachers' planning and teaching.	✓✓✓✓✓✓✓✓✓✓	10

Pre-service teachers were showing evidence of being aware of the level of their teacher development and the areas in which they were lacking. They noted in their reflections how their teaching could be more effective in the future with experience in using the TSPCK framework during the planning of lessons and actual classroom teaching.

Pulane noted that, "…*the more teaching, the more I will learn to use the components*."

Joe mentioned that, in terms of teaching using the TSPCK framework, "…*in planning I was not considering that I was using TSPCK. In future I have to be aware that in planning using TSPCK will improve my teaching methods in the future.*"

Alex stated that, "*My lack of using TSPCK seems to have limited the ability of learners to relate bonding properties of atoms and the chemical properties. A more extensive application of TSPCK, I believe, would make it easier for students to relate these concepts*."

Vuyo was aware of the need for more development based on lesson reflection to improve the quality of teaching, "*In addition, while the quality of TSPCK episodes seemed to increase judging by the number of components found per episode, the quality still needs much improvement and the TSPCK needs to come through more explicitly. This can be done by reflecting using the TSPCK model as a framework to focus reflections. Using the TSPCK model, my reflections at this point of the study [writing a mini research report] are more insightful than reflections during the data collection.*"

Pre-service teachers showed an awareness of the pattern of frequency of the components they were using to plan and teach their lessons, mentioning the need for continuous development to improve the quality of their lesson planning and actual classroom teaching. Jesse noted that, "*Both lessons depicted that CTS, R and CS were the three components that were most frequently used and often integrated with one another*." Comments from Willy noted his most frequently used topics, "*As soon as I was given concern, I started recording my lessons, reflected on them and looked at three components of TSPCK as discussed above (Learner Prior Knowledge, Representations and Curricular Saliency*)." Helen mentioned the specific component she found lacking in her TSPCK maps, "*Looking at the TSPCK episodes what I have realised in most of them is that the component that is not easy to identify in the lesson as part of a TSPCK episode is 'what is difficult to understand'.*

Pre-service teachers were able to notice shortfalls in their use of TSPCK components in their planning and teaching, mentioning the need for continuous development to improve the quality of their lesson planning and actual classroom teaching.

5.5 Conclusion

The views expressed by pre-service science teachers regarding TSPCK and science teaching revealed several commonalities. Firstly, pre-service teachers acknowledge the need for the transformation of content knowledge in order to effectively teach. They also found the TSPCK framework as taught in the methodology class useful to their development as teachers. They noted that, as a result of completing their mini-project, they were able to note aspects in their teaching and planning approaches that still needed to be developed. Pre-service teachers still following traditional beliefs recognised this tendency towards teacher-centre approaches, mentioning, as Vuyo did, that these were aspects that needed development upon reflection.

The pre-service science teachers also shared that they had gained insights into the complexity of actual classroom teaching when comparing the TSPCK maps of their lesson planning to the TSPCK maps of their classroom teaching. They found that they taught using more expanded versions of the planned TSPCK maps. The observations made by pre-service science teachers regarding their development in terms of the less commonly used TSPCK components in planning and classroom teaching were reflected in the previous chapter when I analysed the same data, adding credibility to the findings made. Analysis of the structured questions according to the belief rubric indicated that the pre-service teachers had views about teaching approaches in the transitional teaching approach range, leaning more toward a learner-centred teaching approach rather than the more basic traditional, learner-centred approach.

Chapter 6: Discussions and Implications

This chapter discusses the findings made in this study by first providing an overview of the problem statement that initiated this study and its relation to the theoretical framework that guided the analysis of the data. The research questions are answered and discussed in relation to the findings to show the contributions of the study to existing literature. The chapter is concluded with critical reflections of the research process with regards to the methodology, reliability, trustworthiness and limitations of the study. I conclude the chapter by adding recommendations for further studies in this field.

6.1. Introduction and Overview of the Study

The preparation of pre-service teachers to close the theory-practice gap is an issue of concern in Initial Teacher Education (ITE) programmes (Makgato and Mji, 2006). In the previous Chapters, I have outlined how the science education community values and regards Pedagogical Content Knowledge (PCK) as the knowledge enabling the learning of how to teach science topics. In the literature review I discussed how the construct of PCK has been re-conceptualized for operation in ITE as Topic Specific Pedagogical Content Knowledge (TSPCK). I have further indicated how TSPCK is recognized by the science community as shown by its inclusion in the consensus model of PCK (Gess- Newsome, 2015), and more explicitly in the refined consensus model of PCK emerging from the recent PCK Summit II (unpublished yet, Leiden, December 2016). I have also shared on a few studies that have successfully used the theoretical construct of TSPCK in improving the quality of pre-service teachers' TSPCK in core specific topics in physics and chemistry. Against this backdrop, I have also pointed out that little is known about how pre-service teachers use the construct from their well-reasoned lesson plans into classroom delivery during their practicum, and whether they recognize the extent and limitations of their effort. This informed the purpose of the study, which was to illuminate the nature and the patterns of pedagogical transformation as seen through TSPCK component interactions used by pre-service teachers from their well-reasoned lessons plans to actual classroom delivery.

In the discussion below I answer the research question guiding this study, reflecting on the findings answering each of the sub-questions. The first research sub-question focused on the patterns of the evidence reported by the pre-service teachers of pedagogical transformation of content knowledge. They compared the transformations occurring in their own lesson plans and how these were enacted out in classroom delivery. The second research question investigated the views they held with regard to using the TSPCK framework that seeks pedagogical transformation of content knowledge in their teaching. I will now unpack the findings made during analysis in relation to the research questions.

6.2 Answering the Research Question

What changes, if any, do TSPCK observed in lesson planning undergo when the well reasoned lesson plans are enacted out in the complexity of classroom practice?

The main research question is investigated through three sub-research questions:

i. What patterns of TSPCK component interactions are observed emerging from pre-service science teachers' planning and actual classroom teaching of a physical science topic?
ii. How do such patterns differ from those reported by pre-service teachers from their self-analysis of their planning and its enactement into classroom practice?
iii. What views do pre-service teachers hold about the value of TSPCK in their teaching, particularly with respect to changes in their TSPCK (if any) from planning to practice?

The research question, divided into sub-questions in order to describe the three aspects of pre-service teachers' pedagogical development involving recognition of TSPCK components in their planning and actual classroom teaching, noting the expansion of TSPCK episodes that emerged during classroom teaching and the views they have about the teaching of science.

6.2.1. What patterns of TSPCK component interactions are observed emerging from pre-service science teachers' planning and actual classroom teaching of a physical science topic?

Data analysis in Chapter 4 revealed key findings answering the first two subquestions, that the pedagogical transformation of content knowledge initially demonstrated commonly as a 'single TSPCK episode' of three components in the pre-service teachers' lesson plans, was expanded into sophistication when acted out in classroom lessons to a 'cluster TSPCK episode'.

It is important to recall that pedagogical transformation of content knowledge in this study is measured by the visible extent of interaction of the TSPCK components. Each interaction of two or more TSPCK components was defined as a TSPCK episode. The increase in sophistication of the TSPCK episodes in classroom practice could be confirmed as an expansion of the original episode in the lesson plan into a cluster made up of additional TSPCK epsodes. Some of the additional episodes had increased in the number of TSPCK components involved in the interaction , as was shown in Chapter 4, Figure 4.5, of Zandi's first lesson re-illustrated below.

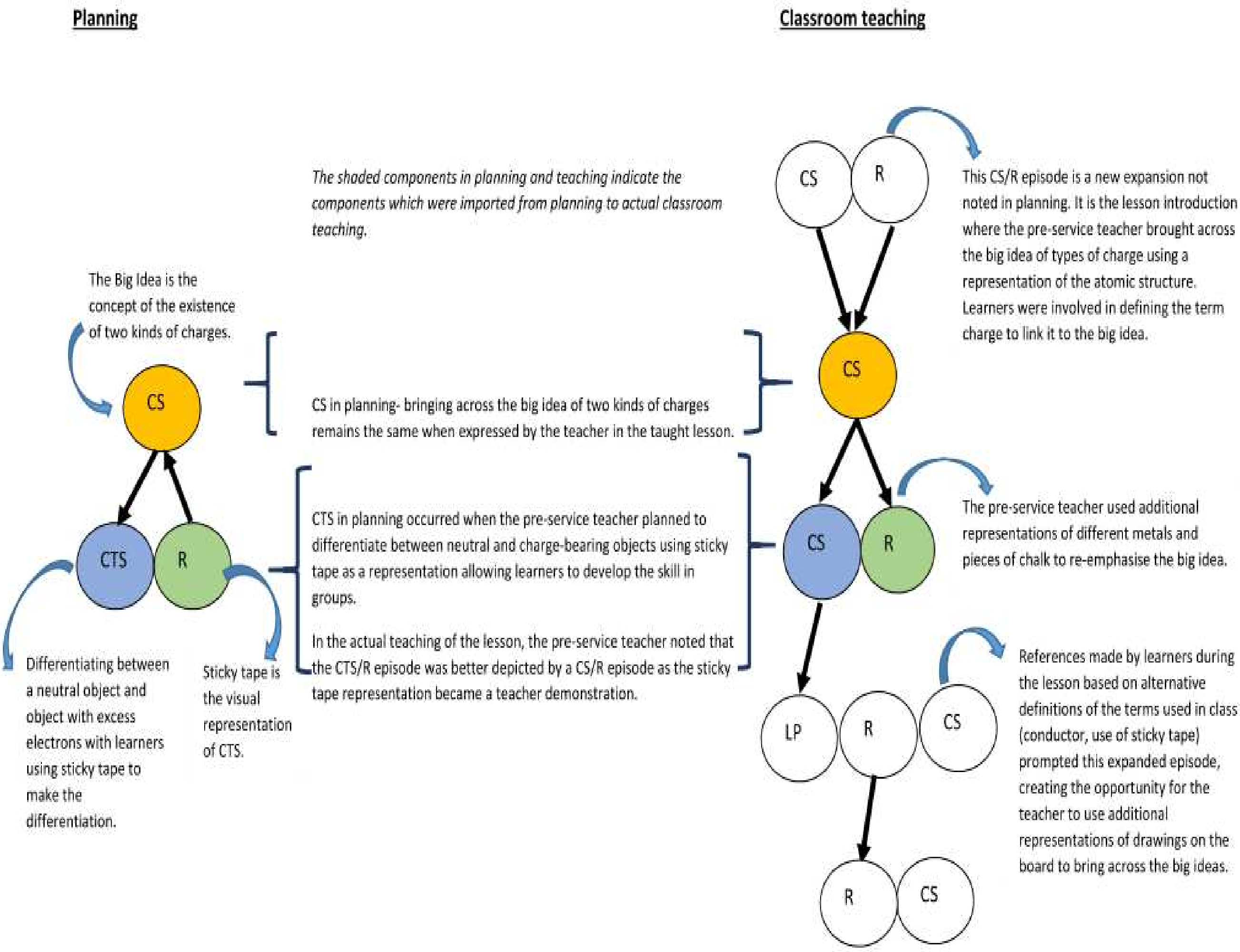


Figure 6.1. TSPCK map comparison of Zandi's first lesson showing the expansion of TSPCK episode in classroom enactment.

In the lesson plan as featured in the left hand side of Figure 4.5, the big idea (CS) brought across to the learners was about the existence of two kinds of charges. Zandi planned a to use a conceptual Teaching Strategy (CTS) to of comparing the two charges and differentiating between a neutral object, electron-deficient object and an electron-rich object, which integrated with the component of representations (R) as he planned to use sticky tape as part of his visual representation of attractive electrostatic forces.

The actual classroom teaching TSPCK episodes featured in the right hand side of Figure 4.3 expressed the same big idea,with the original planned TSPCK episode in colour to indicate where the episode exhibited itself in the actual delivery of the lesson.The sequencing of the lesson was expanded first reflecting awareness of the pre-service teacher of the need for discussing pre-concepts (structure of an atom) before discussing charges. The expansion is noticed again much further into the lesson with an additional TSPCK Episode LP/R/CS which occurred due to the interactions the teacher had with the learners. The pre-service teacher seem to have noted that the learner prior knowledge (LP) was focussing on the everyday definitions of the terminology used. He then added more representations displaying different types of charges before summarising with equations representing the concepts.

i. The complexity of the classroom situation and the effect of the learner interactions on the planned lesson changed the nature of the planned TSPCK Episodes into a 'cluster TSPCK episode' as the teacher embraced the need of pre-requisite knowledge and the emerging organic learner interactions. There was an expansion of the TSPCK episode, while still maintaining the essence of the planned lesson.

6.2.2 How do such patterns differ from those reported by pre-service teachers from their self-analysis of their planning and its enactement into classroom practice?

In summary, the examples shown above indicate the nature of presented analysis of lesson plans and teaching classroom which I have been in agreement with. The level of agreement between myself and the pre-service teachers were the same for their lesson plans as actual classroom teaching transcripts. As mentioned, establishing this agreement was important in determining the authenticity of the patterns.

6.2.3 What views do pre-service teachers hold about using TSCPK in their own teaching?

In chapter 5 the views expressed by pre-service teachers in their mini-research projects were generally displaying a positive regard for the TSPCK framework.

Pre-service teachers felt that they had gained practical teaching skills and confidence during their teaching experiences and reflective practices during the compilation of their mini-research reports. They therefore began to gain a deeper understanding of how to plan and teach more effectively, influencing their commitment to their own development as teachers (Goldman and Grimbeek, 2014).

I now discuss the meaning and the implications derived from the findings from the perspective of the purpose of the study and the new knowledge suggested.

6.3 Meaning of Findings and the New Knowledge Suggested.

6.3.1 Revealing the expansion of pedagogical transformation of CK from well-reasoned lesson plans into classroom delivery.

(i) The patterns

The findings to the first question point to the expansion of pedagogical transformation of CK seen in pedagogically well-reasoned lesson plans changing to a format that is more complicated when lessons are delivered in the classroom. One can regard the lesson plans as 'well-reasoned' because the lesson plans exhibited episodes of TSPCK (see Figure 4.1 in Chapter 4). Furthermore the pre-service teachers were involved in an explicit intervention, thus the knowledge about TSPCK could be assumed reasonably fresh in their minds. This finding is expected to some degree as literature points to the fact that classroom practices are more complex environment as compared to lesson planning that happens in a controlled environment (Madden, 2014). The complexicity is part of the struggle that pre-service teachers and beginning teachers face in applying their theory to practice. What is however new, revealed by this finding, is the uncovering and the illumination of the forms to which 'planned TSPCK episodes' metamorphose into when they are 'enacted in a classroom context'. The observation that a well pedagogically reasoned explanation on paper (plan) expands into a cluster of combinations of smaller explanations that also have evidence of pedagogical transformation is exciting (Figure, 4.4 from Chapter 4). The smaller explanations surround the original explanation which in itself has been transfigured to have more depth in component interaction. Looking closely at the explanatory notes associated with TSPCK episodes provided by pre-service teachers in their mini-research reports, it emerges that the possible source of the increase in the number of TSPCK episodes, point to increased teacher-learner interactions or evident moves by the teacher in acknowledging learner knowledge in a particular instant.

The sophistication of the expanded TSPCK episodes was noted in more frequently-used components repeating in an episode. For example a TSPCK episode in the planning context would have two components say LP and CS, in the classroom context the episode shows the components to be repeating see example of TSPCK in the second lesson of Sipho in an extract from Table 4.4.

Table 6.1. Number of episodes present in planning and teaching, extract.

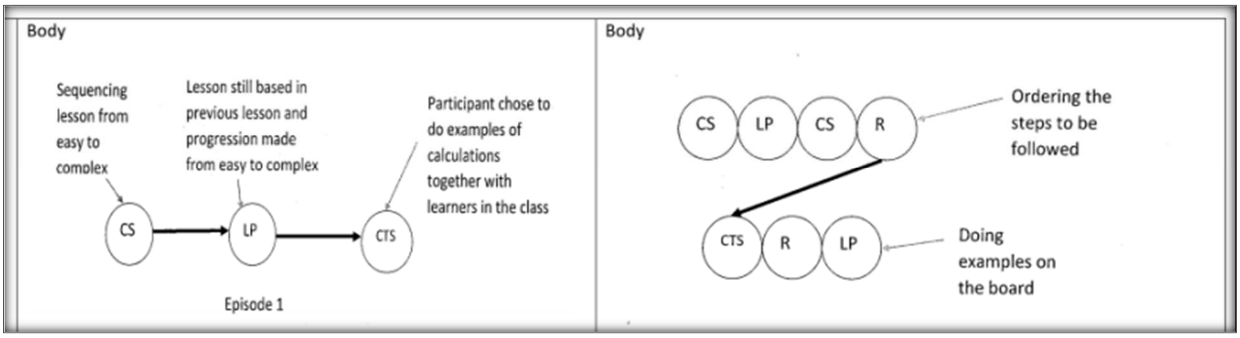
Participant	Lesson number	Number of episodes present in the lesson plan	Number of episodes present in the actual teaching segment	Components featured in the episodes for planning	Components featured in the episodes for actual teaching
Zandi	1	1	4	EPISODE 1	EPISODE 1
				CS-CTS/R	CS/R-CS
					EPISODE 2
					CS/R
					EPISODE 3
					LP/R/CS
					EPISODE 4
					R/CS

Comparison of the TSPCK maps of the planned lesson versus the exhibited classroom lesson showed the repitition of the R, and CS components as the episode expanded from the planned episode to the four episodes in actual classroom teaching. This repetition indicates that the pre-service teacher was using the same component-dynamic to bring the concept through to the learners to ensure understanding.

Also observed, however at a lesser frequency were cases where episodes that displayed interactions of two or three TSPCK components in the lesson plan now displayed interaction of more components. This seemed to have been been prompted by the recognition of the response from learners on previous questions that the teacher now becomes at pains to explain a new concept in relation to what has just occurred or revealed about what learners know.

An example of such a case is seen in the TSPCK Episodes of Jane in Table 4.3 in Chapter 4 where the episode 1 was a three component episode and played out in the classroom as a four component episode, where the fourth component is a repeating component

Table 6.2. An example of the classroom teaching episode revealing sophistication in increased component use by Jane, extracted



The first aspect observed is that episodes with greater number of components interacting were regarded as more sophisticated than those with less components. The value of the finding that the conversion of a 'single TSPCK episode' into a 'cluster TSPCK episode' provides the empirical evidence that exposes the teachers moves in response to the complexity in actual classroom settings. Providing us with language to explain the difference of complexicity from planning a well reasoned lesson into classroom delivery from the perspective of TSPCK component interactions. As noted by Shulman (1986) teachers turn and twist their knowledge as they respond to the demands posed by the diversity and learner interactions that happen in a classroom setting. We now have a possible description of what that process looks like from the perspective of component interactions.

The second aspect of the observations about the expanded pedagogical transformation of CK, is that the original planned intentions as noted by the TSPCK episode in the lesson plan are vividly distinguishable in the expanded form. The meaning implies that the intended explanation is delivered in the lesson and not lost by the moves of the teacher as they establish the needed pre-knowledge, nor by the demands posed on him/her from the classroom interactions. This is generally a characteristic observed in teachers with many years of teaching experience who seem to be more fluent in their teaching delivery, but remaining on course. This character I have personally observed in separate instances from this study, in my evaluation of teachers lessons at schools as a Head of Department in sciences, and I think it confirms Shulman's concession (1987) that pedagogical reasoning of lessons before the actual delivery is as important as the delivery itself, as it informs the reasons for classroom actions.

The observation of this characteristic in pre-service teachers, way before they graduate, reflects and confirms the value of TSPCK as professional knowledge.

The last aspect observed was that in the TSPCK episodes seen in the classroom lessons certain components of TSPCK were more commonly and repeatedly used than others. The TSPCK components of (i) curricular saliency, (ii) learner prior knowledge and (iii)representations. The evidence is based on the presented ratio count of components from Table 4.5 in Chapter 4. This finding confirms the findings made by Aydin et al (2013), Pitjeng (2013), Akinyemi (2015) and Mavhunga (2015) where the same components featured more predominantly in TSPCK maps analysed for their study of pre-service teachers. Aydin and Boz (2013), described these components as components that reveal the specific nature of PCK. This indicates that there is a general trend by pre-service teachers to rely on these components during planning and actual classroom teaching. The less frequently used components, namely What is difficult to understand as well as conceptual teaching strategies, have generally been associated with the teaching practices of more experienced teachers, signalling perhaps that some of the TSPCK components only fully develop with practice and experience as noted by Nilsson (2008),and Botha and Reddy (2011).

The literature also points that although these three components are commonly used in the pedagogical transformation of content by pre-service teachers, they are however, experienced with different levels of difficulty in different topics. For example, Rollnick & Mavhunga, (2013) found in developing TSPCK in Chemical Equilibrium, Learner Prior Knowledge was found to be least difficult and conceptual teaching strategies to be most difficult. The study by Akinyemi, 2015 in a physics topics Kinematics found the order to be: What is difficult to teach and representations as least idifficult followed by Learner prior knowledge, Conceptual teaching strategies and curricular saliency. This obesrvation indicates the possibility of difference due to the topic specificity in which they are used.

(ii) The authenticity of the patterns

A very important point to be noted about the major findings discussed above, is that the they were observed and reported by the pre-service teachers as patterns emerging from their own planning and teaching in their own. The reporting was in the form of a mini-research report that they needed to write as part of an assignment in the course. They were requested to submit both their analysis reports, the raw audio recordings of their lessons and the accompanying lesson plans. In the submitted mini-research reports, they were asked to identify teaching segments from their lesson recordings and lesson plans that displays TSPCK interaction of one or more TSPCK components. As a researcher, I had access to both their mini-research reports where they reported on their analysis and also the raw data (lesson recordings and lesson plans) from which their analysis was based. I observed that their analysis, of their own data, revealed that pre-service teachers were able to authentically identify TSPCK episodes evident in their lesson planning and in their actual classroom teaching. Authentication was established as the agreement between the pre-service teachers' analyses of TSPCK observed in their lesson plans and classroom practice with my analysis of the same evidence, as seen in Chapter 4, Table 4.1 re-illustrated here.

Table 6.3. Overview of the agreement of analyses for TSPCK episodes in planning and classroom teaching

Pre-service teacher	**Lesson planning**		**Classroom teaching**		**Verdict**
Column	1	2	3	4	5
	Episodes identified by pre-service teachers	Episodes identified by researcher	Episodes identified by pre-service teachers	Episodes identified by researcher	
Sipho	6	6	8	8	Good agreement
Pulane	2	2	2	2	Good agreement
Jane	8	8	11	11	Good agreement
Joe	2	2	2	2	Good agreement
Alex	3	3	3	3	Good agreement
Buhle	6	6	12	12	Good Agreement
Willy	1	1	2	2	Good agreement
Philani	2	2	4	4	Good agreement
Mpho	7	7	6	6	Good agreement

Pre-service teacher	Lesson planning		Classroom teaching		Verdict
Column	1	2	3	4	5
	Episodes identified by pre-service teachers	Episodes identified by researcher	Episodes identified by pre-service teachers	Episodes identified by researcher	
Zandi	3	3	4	4	Good agreement
Debra	2	2	4	4	Good agreement
Helen	3	3	3	2	Good agreement
Elias	3	1	3	3	Moderate agreement
Jesse	3	3	9	6	Moderate agreement
Masego	4	3	3	2	Moderate agreement
Vuyo	1	1	5	4	Moderate agreement
Jack	5	3	6	3	Moderate agreement
Thapelo	3	1	3	1	Moderate agreement
Patience	1	0	4	4	Moderate agreement
Jonah	11	3	16	4	Poor agreement
Nonhlanhla	0	0	3	1	Poor agreement
Tony	7	7	9	-	Poor agreement, no transcripts to make confirmation

Pre-service teacher	Lesson planning		Classroom teaching		Verdict
Column	1	2	3	4	5
	Episodes identified by pre-service teachers	Episodes identified by researcher	Episodes identified by pre-service teachers	Episodes identified by researcher	
Petrus	-	-	3	3	Poor agreement, no transcripts to make confirmation

I used the same analysis technique as they were instructed to do as I identified teaching segments, identified a TSPCK episode and analysed components and interactions. There was good agreement reached between my analysis and that of the pre-service teachers, as well as their analysis of the sequence in which components appeared. Table 4.1 showed the level of agreement reached with 52,3% of the analysed data showing good agreement, 30,3% showing moderate agreement and only 17,4% showing poor agreement. Agreement in analysis validated the primary data and allowed for more reliable secondary data.

Pre-service teachers effectively used the concept of PCK episodes adapted from Park and Chen (2012) as their working definition and the framework of TSPCK from Mavhunga (2012) from which to draw their TSPCK maps. Based on their analysis, three key findings as discussed above emerged. The first is that they noticed the expansion of TSPCK episodes (pedagogical transformation) in a lesson plan – a planning context into a cluster of TSPCK episodes that are more sophisticated than those in the planning context, as discussed above. Secondly, that TSPCK episodes generated from specifically planned intentions could be vividly distinguishable in the classroom delivery as clusters of episodes, as also discussed above and lastly, they noticed curricular saliency, learner prior knowledge and representations as TSPCK components that were more occuring in their identified TSPCK components as seen in Table 4.5 in Chapter 4.

Table 6.4. Frequency count of the components evident in the TSPCK episodes in planning and teaching.

Frequency count of components for planning versus teaching												
Participants		Components present in planning						Components present in teaching				
		LP	CS	DIF	R	CTS		LP	CS	DIF	R	CTS
Sipho		5	5	3	6	1		6	6	4	6	0
Jane		4	8	3	2	2		6	6	4	1	5
Buhle		5	6	2	6	3		12	13	9	12	2
Zandi		0	3	0	1	1		0	0	0	0	0
TOTAL		14	22	8	15	7		24	25	17	19	7
%		21	33	12	23	11		26	27	18	21	7.6
Ratio		1.91	3.00	1.09	2.09	1.00		3.42.	3.55	2.37	2.67	1.00

Finally, my analysis of the TSPCK episodes in pre-service teachers' lesson planning and actual classroom teaching brought to light that the components CTS and DIF were the least frequently used components in both their planning and classroom teaching. I have also described this finding as a significant emerging pattern upon analysis of their TSPCK maps in chapter 4. Pre-service teachers with exposure to the use of TSPCK components in their planning and classroom teaching show the ability to reflect on the strengths and weaknesses of their lessons, mentioning that, had they integrated these components in their planning and classroom teaching, they would have been better able to identify and address learner misconceptions of the topics they had taught. Therefore, teachers with a new awareness of the areas needing development in their teaching approaches would be more likely to correct the shortcomings during future lesson plans and classroom teaching situations, making them more effective teachers than before. This awareness empowers pre-service teachers to prepare and present more strategically effective lessons, (Loughran, 2006) in terms of the conceptual development stimulated among the learners they teach (Shulman, 1992), giving them an advantage when they enter the teaching practice in the future.

The observation that pre-service science teachers were able to authentically identify TSPCK episodes in the planning of their lessons as well as in their teaching segments, indicates that they are aware of the professional knowledge there are developing. Particularly useful for teacher development is how aTSPCK episode changes in complexity and shape as it enables them to plan and enact in classroom contexts. According to Nilsson (2011) it is important that pre-service teachers gain awareness and appreciation of the professional knowledge they are learning. Insights into the different TSPCK episodes evident in planning and teaching illuminate to pre-service teachers the naivité of their planning for more basic episodes, and how to adapt them to become more realistic when comparing them to actual classroom teaching situations. This striving toward more complex panning forms an important part of their TSPCK development.

6.3.2 Revealing the views and the underlying science teacher beliefs

In chapter 5 the views expressed by pre-service teachers in their mini-research projects regarding teaching, TSPCK and science education in general were discussed. Emerging views were grouped according to the common themes derived from the analysis. Two sets of data were analysed to illuminate the themes, one being open views about teaching and the other beliefs they have about science teaching in an examination setting. The content of their responses was different from the above reported evaluation of whether pre-service teachers were aware and authentic about the use of their own professional knowledge. These views sought aspects of their emotions largely in the affective domain, therefore not knowledge per se, rather epistemological standpoints made. Generally, there was a positive view expressed toward science education and the benefits of using the TSPCK framework learnt in the methodology course towards being effective science teachers. Findings on pre-service teachers' views point toward the type of teaching approaches they would be likely to follow, as they filter teaching approaches according to their views (Gess-Newsome, 2015). Pre-service teachers felt that they had gained practical teaching competence and confidence during their teaching experiences and reflective practices as they compiled their mini-research reports. They therefore began to gain a deeper understanding of how to plan and teach more effectively, influencing their commitment to their own development as teachers (Goldman and Grimbeek, 2014).

Pre-service teachers showed evidence of being aware of the level of their teacher development and areas they were lacking which they need to improve in order to be more effective teachers. Table 5.4 indicated that this awareness was visible in the responses of 70% of the participating pre-service teachers.

They noted that during the reflections of their teaching experience in order to complete their mini-projects, they realised that their lesson plans showed only a superficial understanding of the interaction of TSPCK components. The lesson plans were described as traditionally teacher-centred in their approach. Also, the use of TSPCK components in planning and actual teaching of science topics were seen by pre-service teachers to improve teacher awareness of the need to transform content for teaching, promoting a better understanding of the topic by the learners. Nilsson, (2008) mentioned the importance of pre-service teachers developing an awareness of their development as she felt that this would aid in developing the elements they required to transform them to PCK.

Pre-service teachers focused on describing what they considered to be good science teaching and as a result there were five main findings to be made from the analysis of their views on science teaching within the TSPCK framework.

Firstly, pre-service teachers showed evidence of recognising that the teaching of science requires transformation of content knowledge. Shulman, (1986,1987) noted the need for transformation of content knowledge in order for effective teaching and learning to occur, and was clearly echoed by the pre-service teachers. Comments made by pre-service teachers found in Table 5.3 showed that 20 of the 23 participating pre-service teachers, amounting to 87% of the cohort, mentioned this statement. The framework taught to the pre-service teachers in their methodology class was clearly able to instil in them that they would not merely be able to transfer knowledge from a textbook or similar resource material if their intention was to be quality teaching and learning.

Secondly, pre-service teachers expressed that they found value in the TSPCK framework in terms of being able to equip them for entering the teaching profession. Responses as listed in Table 5.1 such as, "*As time passed, I came to a new and deeper understanding of TSPCK. By reflecting on my lesson taught on TE, it allowed me to identify the problems in my teaching. With my new and deeper understanding of TSPCK I am able to develop lessons that promote conceptual transformation of the content*". This extract from Sipho depicted that pre-service teachers noted that the use of TSPCK components promote better knowledge transformation and that using TSPCK components to plan and teach topics creates in teachers a better awareness, enabling better understanding in the learners. Their statements enabled me to triangulate previous similar findings and confirmed the observed high authentic identification of the trail of their TSPCK episodes in planning and teaching as presented in Chapter 4 and discussed in 6.3.2 above. They noted that good science teaching involves developing conceptual understanding in learners. This conceptual understanding could be developed through the transformation of content knowledge by the teacher through the nature of TSPCK component interactions.

Thirdly, pre-service teachers believe that teacher training programmes could benefit from incorporating the TSPCK framework in their approach based on the value they gained in their methodology class. Responses as noted in Table 5.1 showed that 83% of pre-service teachers felt that teacher education programmes incorporating the TSPCK framework will assist pre-service teachers to become more effective teachers. For example, an extract from Nonhlanhla, "*Science teachers should be able to track their own development of PCK and identify elements of PCK in their own teaching. This will enable further research to see where there are loopholes and non-loopholes so that science education programs can change their curriculum and make other changes where needed. The framework will guide future preparation of science education programs.*"

Fourthly, responses from the science teacher belief tools analysed using Beliefs Maps by Luft and Roehrig (2007) as described in chapter 3, showed the level of teaching approach identified to be most prevalent among the group to be at the transitional level. Transitional beliefs were characterised by Luft and Roehrig (2007) as slightly more student-focussed than traditional beliefs. They are seen as transitional beliefs from traditional to more learner-centred reformed type of belief. Previous studies using the beliefs map by Mavhunga and Rollnick, (2015)noted that pre-service teachers' beliefs before intervention concentrated around traditional approaches to teaching. Following a TSPCK-based intervention, the beliefs tended toward a more student-centred approach. The authors reported that the quality of TSPCK was even developed in pre-service teachers who held teacher-centred beliefs (Mavhunga & Rollnick, 2015). Therefore, teacher educators need to be aware that pre-service teachers with learner-centred beliefs could later still be persuaded by to return to teacher-centred beliefs. Contextual factors such as the teaching staff they are surrounded by when they begin to teach may influence this belief system taught during ITE. It is therefore important to lay a strong foundation of beliefs in pre-service teachers enabling them to develop their views further as they teach, to prevent them from slipping into more traditional beliefs. The findings in the Mavhunga (2012) study indicate that the TSPCK intervention in the methodology class has delivered teachers who will be entering the teaching profession with a stronger sense of learner-centred approaches. They would have the skills to apply TSPCK components in their lesson planning and actual classroom teaching to effect a higher standard of teaching as beginner teachers than previously noted in novice teachers. Geddis (1996) stated that the beliefs held by teachers greatly influence the path of instruction in the classroom, and that these beliefs were difficult to transform once well established. Therefore, if the pre-service teachers were already showing signs of more transitional views of teaching approaches, the effect it would have on their classroom delivery could be more effective and subject to improvement than if they entered the teaching arena with traditional teaching approaches.

6.4 Conclusion and Implications

This reflective chapter sets out to show how the research questions were answered by the findings generated through the analysis of the mini-research projects and examinations of the pre-service teachers in their methodology course thereby making a contribution to the existing literature on the development of TSPCK in pre-service teachers.

Pre-service teachers who gain understanding in the importance of gaining sophistication in learning pedagogical transformation, as shown by this study, will consider applying more TSPCK components in their lesson planning, making their pedagogical reasoning that informs classroom activities stronger. ITE programmes now have evidence of the development paths followed by pre-service teachers in terms of their awareness of development, the effectiveness of the use of TSPCK components and evolving views regarding the teaching of science. These aspect, now brought to the forefront, enables ITE programmes to fast-track the learning curves of pre-service teachers as they enter the teaching profession with more skills pertaining to experienced teachers.

It is also important to note that the awareness gained by pre-service teachers regarding the trail followed of developing professional teacher knowledge in clearly distinguished from the views and teacher beliefs expressed by the pre-service teachers. Although both are important in informing ITE programmes, they refer to different aspects of teacher education. The beliefs developed by a pre-service teacher eventually inform the teaching components they rely on the most during teaching (Aydin & Boz, 2013). Knowledge of the existence of the theory-practice gap in ITE enables science teacher educators to focus on the explicit needs of pre-service teachers that were not previously addressed. Pre-service teachers will be more confident and capable of effectively dealing with the complexities of classroom situations while fluidly managing the TSPCK components in order to deliver more understandable lessons to their students.

In conclusion, the findings of this study illuminate the once-tacit aspects of the development occurring in pre-service teachers during their training programmes. These findings would therefore serve as a means to develop ITE with the ability to create teachers who have the ability to teach more effectively as they begin their careers, with an ability to adapt ad monitor their growth in teaching. ITE would be able to assist pre-service teachers in the development of skills in using the components featuring as more difficult, to balance the use of all five components in their teaching practice.

6.5. Reflections on the methodology used

The TSPCK construct used as a theoretical framework in this study developed by Mavhunga (2012) was elaborated upon in later studies aimed at specific science topics (Rollnick & Mavhunga, 2013; Ndlovu, 2013) where the construct was validated. This framework became a valuable guiding tool in this study. The analysis during the comparison between pre-service teachers' lesson plans and actual classroom teaching not only showed which TSPCK components were more frequently used per subject topic, it also indicated the development level of the pre-service teachers in terms of the TSPCK components they relied on most frequently in their planning and actual classroom teaching. The framework also guided the analysis into the expansion of the planned episodes into actual classroom teaching, providing this study with invaluable evidence and insights into the actual mechanisms of exporting a well-reasoned lesson plan into an actually delivered classroom lesson. I was able to note the patterns of common TSPCK components used blossoming into more complex clusters of TSPCK episodes as the lesson plan was used in the classroom. The findings of this study therefore provide a glimpse into a tacit construct being formally represented on paper into a set of component interactions changing as they are applied in an actual classroom situation.

The findings in this study strengthen the findings of the previous studies and allow for a more in-depth look at the nature of the interactions among the components in the topics taught by pre-service teachers. Furthermore, the findings of this study give insights into the views pre-service teachers have about the TSPCK framework itself from the content analysis made of the open-ended questions in their examinations. The advantage of using the two analyses lies in the ability to triangulate the information, verifying patterns formed in one data set with the other. As TSPCK has up to now been viewed as tacit (Mavhunga and Rollnick, 2013) it benefits the study to perform a qualitative analysis of the data in order to determine patterns formed in the triangulation of the data, to identify emerging themes from the participating pre-service teachers as a group. I have used a qualitative case study to collect and analyse data for this study. The case study enables collection of textual data depicting the reality of the pre-service teachers' thoughts and experiences (Cohen, Manion & Morrison, 2000).

Data from the formal setting classified as assessment tasks had the advantage of receiving information from participants after much thought, effort and deliberation. The pre-service teachers had sufficient time to complete the mini-research reports and place their ideas into context. It can be assumed that, as the pre-service teachers knew that they were submitting their reports for marks, they could possibly have distorted some of the evidence by attempting to supply answers that could give them the highest possible marks. I therefore received the benefit of analysing the pre-service teacher's synthesis of their raw data, allowing me the luxury of merely authenticating the data they had generated. This enabled me to perform much more in-depth pattern analysis of the data they supplied, allowing me to conceptualise their knowledge. By triangulating the findings of the mini-research report with the findings of the examination written three weeks later, it gave a greater reliability value to the patterns which did emerge.

The examination questions were analysed according to a rubric of teacher beliefs initially designed by Luft et al. (2007), and further adapted by Mavhunga (2012). This rubric enabled the classification of the views held by pre-service teachers according to a scale of teaching approaches from traditional teacher-centred to learner-centred reform based teaching approaches. Further adaptation was required for it to be effective for this specific study. The rubric criteria were adapted to include a larger variety of examples depicting each criteria as the views expressed by the pre-service teachers were individualistic, and their ideas needed to be included along the criteria scale in order for the rubric to be able to reflect the approach pattern effectively. As a result, the range in which the pre-service teachers' views fitted, since completing the methodology course using the TSPCK framework, showed that they were more advanced in their teaching approaches than I had hypothesised, but still within a developing range, not featuring in the categories indicating greater levels of teaching experience. Data from the rubric and the TSPCK maps together could be used in teacher education programmes as a tool to determine the level of development the pre-service teacher has, making it a valuable aid for further interventions in the process of teacher preparation.

6.6. Reflections on Reliability and Trustworthiness

The data collected consisted of the pre-service teachers' mini-research report of their teaching experience. The reports contained their own analysis of their lesson planning and actual classroom teaching in order to determine the way in which TSPCK components worked together in teaching segments to form TSPCK episodes. They gathered their data from transcript made from the audio recordings of their classroom lessons. The pre-service teachers had undergone TSPCK construct intervention during their methodology course and knew the same working definition of TSPCK as I used for the study. This was confirmed in the write-up of their research reports. Reliability of the analysis of data depended upon the manner in which the identified episodes were confirmed. I used the pre-service teachers' own lesson planning, along with the transcripts of the recordings of their actual classroom lessons in order to find agreement with the episodes and interacting components in the TSPCK maps they presented. Pre-service teacher views were coded and scored according to a piloted rubric, ensuring consistency in the categorisation of the beliefs expressed by the pre-service teachers in their examinations. The results of the analyses were agreed upon by a second rater who supervised the study and data analysis.

I was able to confirm the authenticity by referring to these transcripts, enhancing the trustworthiness of the findings that were made from the data. The second set of data analysed consisted of the pre-service teachers' methodology examinations where they answered structured questions pertaining to their views on science teaching and the application of the TSPCK construct. The views they mentioned in their mini-research reports were also reflected in the answers given during the examination, adding to the trustworthiness of the views they exhibited in their examinations.

The instrument used to analyse the beliefs of pre-service teachers was adapted from the belief rubric designed and piloted by Luft and Roehrig (2007), who used the same structured questions as used in this study, with exception to the first question specifically targeting the use of TSPCK in science teaching. The rubric was also adapted and used by Mavhunga (2012) in her studies on pre-service teacher beliefs on topics in chemistry including chemical equilibrium, with some findings in my study showing the level of teaching approaches exhibited by pre-service teachers correlating with her findings.

During this qualitative study, the representation of the analysis of the data and subsequent findings were presented as thick detailed descriptions that were thoroughly unpacked, and sent to a second rater for reaffirming my analyses of the pre-service teachers' evidence, improving the reliability of the findings. Due to the fact that sufficient details have been supplied to the readers illuminating the patterns emerging from my analyses, it should enable them to be able to reach the same conclusions as the ones I presented in my findings, given the same evidence to work with.

6.7. Limitations of the study

This study was limited in terms of the predetermined size of the sample of 23 pre-service teachers, who were enrolled in the methodology course. This, together with the fact that the research method was a case study, hinders the generalisability of the findings (Bertram et al., 2014).

Due to the fact that both the mini-research report and the examination written by the pre-service teachers, there exists the possibility that the teachers expressed and put additional effort that may not be seen under relaxed conditions. Pre-service teachers were aware of the mark allocations for each of the tasks, and may possibly have answered some of the belief questions with the aim of portraying what they thought was a more acceptable answer as opposed to giving their true views. This was not necessarily the case with the TSPCK episode analysis as they were deriving their data from transcripts of actual classroom lessons and lesson plans.

6.8. Future research and recommendations

Research involving the TSPCK construct is relatively new, and therefore opens a wide area for future research, specifically focusing on long-term study of the effects that TSPCK interventions in the methodology class would have on the quality of teaching exhibited by these teachers, years after entering the teaching profession Knowledge of the development of TSPCK component interactions could be valuable in teacher education programmes where the need arises to "fast-track" certain skill developments in new teachers. These basic interactions could be provided to beginner teachers along with their teaching plans with the intention that their use will make the transformation of content knowledge for teaching to be of a higher standard and effective at a quicker rate than waiting for the teacher to develop these skills with years of teaching experience.

It would serve the education system well if the pre-service teachers had the skills and knowledge to reflect and analyse their reflections in order to make the appropriate adjustments to improve their teaching. In EU countries and the USA, science teacher preparation standards include the need for developing PCK, accordingly, teacher educators recognise the need for an adequate model for teacher preparation as the current models fail to accurately address the role of PCK in science teacher preparation (Nezvalova, 2011). Authors suggest that initial teacher education (ITE) programmes need to focus on PCK, combining it with general knowledge in stages to prepare more effective teachers (Hardiyati & Sutikno, 2015). The findings on areas of strengths and weaknesses in certain knowledge domains prompt rethinking of the structure of initial teacher education programmes to accommodate approaches improving PCK development. (Botha and Reddy, 2011). Although some of the aspects of PCK can only be formed with teaching experience, it becomes evident that the development of sound PCK is crucial during pre-service training. (Botha and Reddy, 2011)

There exists a positive relationship between pre-service teachers' knowledge of PCK and belief in self-efficacy to teach in a classroom. Science education is tending toward bridging the gap between the pedagogical and content aspects of teacher preparation- advocates the development of a cohesive knowledge base (Doster, Jackson & Smith, 1994) by using PCK.

Secondly, as the aim of teacher education programmes is to improve the quality of teaching and learning of science in the classroom, it would be most informative to determine the long-term effect the TSPCK intervention has on learner achievement of the learners taught by the TSPCK methodology teachers, which would in turn, inform future teacher education programmes.

Illumination of the emerging patterns in the TSPCK maps of lesson planning and actual classroom teaching provides empirical evidence of the level of awareness called for by a number of science education researchers in PCK, advocating for ITE programmes to create opportunities for pre-service teachers to develp awareness of their own learning (e.g Nilsson, 2008; Nilsson and Loughran, 2012). Such awareness is different from a mere view that pre-service teachers may have, as such views as will be dicussed in the section below, could be positive but remain far abstract without real conviction and empirical evidence of real impact. Thus, while this finding could be link to an existing discourse in the PCK literature as shown above, the extent of awareness demonstrated, with such high authenticity of provided clear articulation of the theory - practice transfiguration of TSPCK episodes is interestingly encouraging. It demonstrates a desirable calibre of science pre-service teachers who not only are developing the professional teacher knolwedge, but remain in touch with the trail of their actions. The extent of their development demonstrated the depth of experience that long-term teachers do (Botha & Reddy, 2011; van Driel et al, 1998), It therefore stands to reason that they are only partly equipped to plan ahead for all contexts in an actual teaching situation, as was now made clearly visible in the comparison maps.

In terms of science education programmes, pre-service teachers mention that the TSPCK framework assisted them as beginner teachers to teach known topics as well as equipping them to teach topics in the future that they had not dealt with before. Nezvalova (2011) notes that focusing on topic-specific examples, pre-service teachers can focus and develop specific strategies which can later be transferred to other topics based on their content backgrounds. The positive feedback regarding the use of the TSPCK construct could open a pathway for future research explicitly charting the development of pre-service teachers on a component interaction level. This would allow pre-service teachers to gain a better awareness of their development, making them more receptive to attempt to develop the skills necessary to teach more effectively in the future.

References

Ahmed, Z., Lubben, F., & Sadeck, M. (2015). *Teachers' views on the use of socio-scientific scenarios in science teaching*. Paper presented at the Paper presented at the Southern African Association for Research in Mathematics, Science and Technology Education, Maputo, Mocambique.

Álvarez, C. A. (2015). Can teachers teach? An ethnographic study of a teacher. *US-China Education Review*. 5(4)233-244

Akinyemi, O. S. (2015). *Pre-service teachers' development of Topic Specific PCK in Kinematics and transferability of PCK competence to a new physics topic*. (Unpublished master's research report, University of the Witwatersrand, Johannesburg)

Annetta, L.A., & Dotger, S. 2006. Aligning pre-service teacher basic science knowledge with INTASC I and NSTA Core content Standards. *Eurasia Journal of Mathematics, Science and Technology Education.* 2(2). 40-58.

Anney, V.N., Hume, A.C., and Coll, R. 2012. The use of unqualified science teachers in developing countries: A barrier to achieving sustainable global education. Official Conference Proceedings of the Asian Conference on Education, 2012.

Aydin, S., & Boz, Y. (2013). The nature of integration among PCK components: a case study of two experienced chemistry teachers. *Chemistry Education: Research and Practice, 14*, 615-624.

Bertram, C. & Christiansen, I. (2014). *Understanding Research. An introduction to reading research.* Pretoria: van Schaik.

Bishop, K., & Denley, P. (2007). *Learning Science Teaching: Developing a professional knowledge base*: Maidenhead: Open University Press.

Botha, M. L. & Reddy, C. P. S. (2011). In-service teachers' perspectives of pre-service teachers' knowledge domains in science. *South African Journal of Education.* 31, 257-274.

Cohen, L., Manion, L., and Morrison, K. (2000). *Research Methods in Education.* 5th Edition. London: Routledge Falmer.

Creswell, J. (2013). *Research Design: Qualitative. Quantitative and Mixed Methods Approaches 4th Edition.* London: Sage Publications.

Darling-Hammond, L. (1999). *Teacher quality and student achievement: A review of state policy evidence.* Seattle: Centre for the Study of Teaching and Policy.

Dewey, J. (1910). *How we think.* In: The problem of training thought. Heath and Co. Boston: DC.

Dewey, J. (1966). *Democracy and Education*. New York: MacMillan.

De Swart, H. C., du Toit, H. S., & Botha, A. (2012). Guided reflection as a tool to deal with the theory-practice gap in critical care nursing students. *Health SA Gesondheid. Journal of*

Interdisciplinary Health sciences. 17(1) Downloaded in August 2017 from http://dx.doi.org/10.4102/hsag.v17:1.591.

Doster, E., Jackson, D., & Smith, D. (1997). Modelling Pedagogical Content Knowledge in Physical Science for Prospective Middle School Teachers: Problems and Possibilities. *Teacher Education Quarterly,24* (4), 51-65.

Eilam, B., & Poyas, Y. (2009). Learning to teach: enhancing pre-service teachers' awareness of the complexity of teaching-learning processes. *Teachers and Teaching,* 15(1) 87-107.

Geddis, A. N. (1993). Transforming subject-matter knowledge: the role of pedagogical content knowledge in learning to reflect on teaching. *International Journal of Science Education, 15, 673-683.*

Geddis, A. N. (1996). Science, teaching and reflection: Incorporating new subject matter into teachers' classroom frames. *International Journal of Science Education, 18(2) 249-265.*

Geddis, A. N., & Wood, E. (1997). Transforming Subject Matter and Managing Dilemmas: A Case Study in Teacher Education. *Teaching and Teacher Education, 13*(6), 611-626.

Gess-Newsome, J. A model of teacher professional Knowledge and skill including PCK: Results of the thinking from the PCK Summit. In Berry, A., Friedrichsen, P., & J. Loughran, (Eds). (2015). *Re-examining Pedagogical Content knowledge in Science Education.* New York: Routledge.

Goldman, J. D., & Grimbeek, P. (2015). Pre-service primary school teachers' self-reflective competencies in their own teaching. *European Journal of Psychology Education,* 30, 189-207.

Goode, J. (2011). Rethinking Technology in Teacher Education: Developing the knowledge and dispositions of cuborg teachers. In: I.M. Saleh, M. Skhine, (Eds). Teaching Teachers. New York: Nova Science Publishers Inc.

Gravett, S., & Petersen, N. (2015). Establishing teaching schools in South Africa. University of Johannesburg.

Grossman, P. L. (1990). *The making of a teacher: teacher knowledge and teacher education*. New York: Teachers College.

Grossman, P. L., Wilson, S. M., & Shulman, L. S. (1989*). Teachers of substance: Subject matter knowledge for teaching*. In: Knowledge base for the beginning teacher. M. C. Reynolds, (Ed). New York: Pergamon.

Grossman, P.L., Hammerness, K., and McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching: Theory and Practice*, 15(2), 273-289

Hartadiyati, E. W. H., & Sutikno. (2015). Self-efficacy as affective domain of pedagogy content knowledge (PCK): Implications for pre-service teachers and in-service teachers in science teaching. *International Journal of Educational Research.* 3(1), 391-404.

Hashweh, M. Z. (1996). Effects of science teachers' epistemological beliefs in teaching. *Journal of Research in Science Teaching.* 33, 47-64

Horng, J. S., Lin, C. L., ChanLin, L. J. (2008). Competency disparity between pre-service teacher education and teaching requirements in Taiwan. *International Journal of Educational Development.* 1(28), 4-20.

Hume, A. and Berry, A. 2011. Constructing CoRes- a strategy for building PCK in pre-service Science Teacher Education. *Journal of Research in Science Education.* 41, 341-355.

Jonsson, A., and Svingby, G. (2007). The use of scoring rubrics: Reliability, validity and educational consequences. *Educational Research Review.* 2, 130-144.

Karişan, D., Şenay, A. & Ubuz, B. 2013. A science teacher's PCK in classes with different academic success levels. *Journal of Educational and Instructional Studies in the World,* 3, 1(4), 22-31.

Kind, V. (2009). Pedagogical content knowledge in science education: Perspectives and potential for progress. *Studies in Science Education*, 45(2), 169-204.

Kind, V. (2010). *United Kingdom: Basic structure of the education system*. In: B. Risch (Ed), Teaching chemistry around the world. Waxmann Verlag GmbH.

Kislov, R. (2014). Rethinking capacity building for knowledge mobilisation: developing multilevel capabilities in healthcare organisations. *Implementation Science.* 49. 166

Korthagen, F.A.J. (1993). Two modes of reflection. *Teacher and Teacher education,* 9(3), 317-326.

Korthagen, F.A.J. (2001). Linking practice and theory: The pedagogy of realistic teacher education. Paper presented at the Annual Meeting of the American Education Research Association, Seattle, April 2001.

Korthagen, F.A.J. (2010). The relationship between theory and practice. In: P. Peterson, ed. *International Encycopedia of Education,* 7, 669-675.

Leiden, 2016. Discussions held at the proceedings of the PCK summit, unpublished. Leiden.

Loughran,J.J., Berry, A. & Mulhall, P. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching, 41(4), 370-391.*

Loughran, J. J., Berry, A., & Mulhall, P. (2006). *Understanding and developing science teachers Pedagogical content knowledge*. Rotterdam: Sense Publishers.

Loughran, J. J. (2007). Researching teacher education practices: Responding to the Challenges, Demands, and Expectations of self-study. *Journal of Teacher Education, 58* (12), 12-20.

Loughran, J.J., & Hamilton, M. (2016). Developing an Understanding of Teacher Education. In J. Loughran, & M. Hamilton (Eds.), *International Handbook of Teacher Education* (Vol. 1, pp. 3-22). Singapore: Springer.

Luft, J. A., Hill, K., Nixon, R., Campbell, B., & Dubois, S. (2015). The knowledge needed to teach science: Approaches, Implications, and Potential Research. *Paper presented at the Association for Science Teacher Education meeting, Portland, OR, 2015.*

Luft, J., & Roehrig, G. H. (2007). Capturing Science Teachers' Epistemological Beliefs: The Development of the Teacher Beliefs Interview. *Electronic Journal of Science Education, 11*(2).

Magnusson, S., Krajcik, J., & Borko, H. (1999*). Nature, sources and development of pedagogical content knowledge.* In J. Gess-Newsome & N. G. Lederman (Eds.), Examining pedagogocal content knowledge. P95-132. Dordrecht:Kluwer Academic Publishers.

Mavhunga, M. E. (2012). *Explicit Inclusion of Topic Specific Knowledge for Teaching and Development of PCK in Pre-service Science Teachers. (Doctoral Thesis, University of the Witwatersrand).*

Mavhunga, M. E. (2014).*Improving PCK and CK in Chemistry pre-service teachers.* In M. Askew, M. Venkat, M. Rollnick & J. Loughran (Eds.), Exploring content knowledge for teaching science and mathematics: Windows into teacher thinking. (p29-49). Abington, UK: Routledge.

Mavhunga, M. E. (2015). *The Nature of Interactions of the Components of Topic Specific Pedagogical Content Knowledge*. Paper presented at the Paper presented at the Southern African Association for Research in Mathematics, Science and Technology Education, Maputo, Mocambique.

Mavhunga, M. E. (2015). *Is topic specific pedagogical content knowledge (TSPCK) a possible answer to the theory – classroom practice gap?* Paper presented at the South African Education Research Association (SAERA), Bloemfontein.

Mavhunga, M, E. (2016). Transfer of the pedagogical transformation competence across

Chemistry topics. *Chemistry Education Research and Practice*. 17, 1081 – 1097.

Mavhunga, M. E. & Rollnick, M. (2013). Improving PCK of Chemical Equilibrium in Pre-service Teachers. *African Journal of Research in Mathematics, Science and Technology Education,* 17, 1-2, 113-125.

Mavhunga, M. E. & Rollnick, M. (2015). Teacher- or Learner-Centred? Science Teacher Beliefs Related to Topic Specific Pedagogical Content Knowledge: A South African Case Study. Research in Science Education. *Research in Science Education.* DOI: 10.1007/511165-015-9483-9.

Mavhunga, M. E. & Rollnick, M. (2017) Implementing PCK topic by topic in methodology courses- a case study in South Africa. Downloaded on 29 August 2017 from http://dx.doi.org/10.1007/978-94-6300-881-5_9.

McDonald, J. T. & Dominguez, 2010 L. A. Professional Preparation for Science teachers in Environmental Education. In A.M. Bodzin et al. (Eds.). *The Inclusion of Environmental Education in Science Teacher Education.* 2010. DOI 10.1007/978-90-481-9222-9_2. Springer Science + Business Media B.V. p 17-30

McDonough, G. P. (2012). Teaching practitioners about Theory and Practice: A Proposal to Recover Aristotle in Teacher Education. *Journal of Thought*. 7-22.

McDuffie, A. R. (2004). Mathematics teaching as a deliberate practice: an investigation of elementary pre-service teachers' reflective thinking during student teaching. *Journal of Mathematics Teacher Education,* 7, 33-61.

Mihladiz, G. & Timur, B. 2011. Pre-service Science Teachers Views of In-service Science Teachers' Pedagogical content knowledge. *Eurasian Journal of Physics and Chemistry Education.* 1, 89-100.

Makgato, M. & Mji, A. (2006). Factors associated with high school learners' poor performance: a spotlight on mathematics and physical science. *SA Journal of Education.* 26(2), 253-266.

Morris, A. K. (2006). Assessing pre-service teachers' skills for analysing teaching. *Journal of Mathematics Teacher Education.* 9, 471-505.

Ndlovu, M. (2013). *The design of an instrument to measure physical science teachers' topic specific pedagogical content knowledge in electrochemistry.* Masters, University of the Witwatersrand, Johannesburg, South Africa. Retrieved from http://wiredspace.wits.ac.za/bitstream/handle/10539/14920/

Nezvalová, D. 2011. Researching Science Teacher Pedagogical Content Knowledge. *Problems of Education in the 21st Century.* 35, 104-118.

Nilsson, P. (2008). Recognizing the need- Student teachers' learning to teach from teaching. *Nordina* 4(1).

Nilsson, P., & van Driel, J. (2011). How will we understand what we teach? - Primary Student teachers' Perceptions of their development of knowledge and attitudes towards Physics. *Research in Science Education,* 41, 541-560.

Nilsson, P., & Loughran, J. (2011). Exploring the development of pre-service science elementary teachers' pedagogical content knowledge. *Journal of Science Teacher Education.*

Nilsson, P., & Loughran, J. (2012). Exploring the development of pre-service science elementary teachers' pedagogical content knowledge. *Journal of Science Teacher Education,* 23, 699-721.

Opie, C. (2004). *Doing educational research.* London, United Kingdom of Briton: SAGE Publishers.

Park, S., & Chen, Y. (2012). Mapping out the integration of the components of pedagogical content knowledge (PCK): Examples from High School Biology classrooms. *Journal of Research in Science Teaching, 49(7), 922-941.*

Pitjeng, P. (2013). *Measuring topic specific PCK in particle nature of matter in novice science teachers* Paper presented at the 21st Annual Meeting of the Southern African Association for Research in Mathematics, Science and Technology Education Western Cape, Cape Town.

Rollnick, M., Bennet, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education,* 30(10), 1365-1387.

Rule, P. and John, V. 2011. *Your guide to case study research.* Pretoria: van Schaik.

Schőn, D. (1983). *The reflective practitioner*. New York: Basic books.

Shulman. L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 4-14.

Shulman L. S. (1987). Learning to teach. *American Association of Higher Education,* 40, 1-5.

Shulman, L. S. (1992). "Research on teaching: A historical & personal perspective." In F. Oser, A. Dick, & J. Patry (Eds.), *Effective and responsible teaching: The new synthesis*. San Francisco: Jossey-Bass: 14-29.

Shulman, L. (2015). PCK: Its genesis and exodus. In A. Berry, P. Friedrichsen, & J. Loughran, *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 3-13). New York: Routledge.

Spaull, N. (2013). *South Africa's education crisis: The quality of education in South Africa 1994–2011.* Retrieved March 2016, 15, from Centre for Development and Enterprise:

Van Zyl, A. E. (2014). Exploring the potential theory-practice gap in the teaching methods of nurse educators. Dissertation presented in partial fulfilment of the requirements for degree of Master of Philosophy in the Faculty of Education. Stellenbosch University.

Veal, W. R., & Makinster, J. G. (1999). Pedagogical content knowledge taxonomies. *Electronic Journal of Science Education*, 3(4), 1-18.

Zhou, S., Wang, Y., & Zhang, C. (2015). Pre-service Science Teachers' PCK: Inconsistency of pre-Service Teachers' Predictions and Student Learning Difficulties in Newton's Third Law. *Eurasia Journal of Mathematics, Science & Technology Education.* 12(3), 373-385.

Appendix 1. Ethics clearance forms granting permission to conduct the research of this study.

Wits School of Education

WITS UNIVERSITY

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

26 April 2016

Student Number: 769102

Protocol Number: **2016ECE008M**

Dear Denise van Der Merwe

Application for Ethics Clearance: Master of Science

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

Examining pre-service teachers' reflections on their classroom teaching in order to identify Topic Specific Pedagogical Content Knowledge in their practice

The committee recently met and I am pleased to inform you that **clearance was granted**. However, there were a few small issues which the committee would appreciate you attending to before embarking on your research.

The following comments were made:

- Participation information sheet: Provide reasons for audiotaping
- Principal Investigator and Head of School Information sheet:
  - Although the details are useful, try and summarise your intentions. Avoid repetition.
  - Use more paragraphs to improve readability.
  - There are grammatical errors in the following paragraphs: First – in the sentence that begins with – "I anticipate the need to …". The second – "In order to answer …". The third – punctuation error

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,

MMabety

Wits School of Education

011 717-3416
Cc Supervisor: Dr Elizabeth Mavhunga

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

OFFICE OF THE REGISTRAR

Ms Denise van der Merwe
Student number 769102
M.Sc research in Science Education

TO WHOM IT MAY CONCERN

"Examining pre-service teachers' reflections on their classroom teaching in order to identify Topic Specific Pedagogical Content Knowledge in their practice"

This letter serves to confirm that the above project has received permission to be conducted on University premises, and/or involving staff and/or students of the University as research participants. In undertaking this research, you agree to abide by all University regulations for conducting research on campus and to respect participants' rights to withdraw from participation at any time.

This notice serves as proof that the University's internal mailing system may be used as the mechanism by which potential participants can be approached.

If you are conducting research on certain student cohorts, year groups or courses within specific Schools and within the teaching term, permission must be sought from Heads of School or individual academics.

The necessary ethical clearance has been obtained.

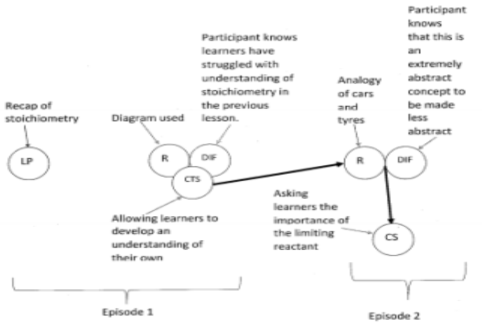
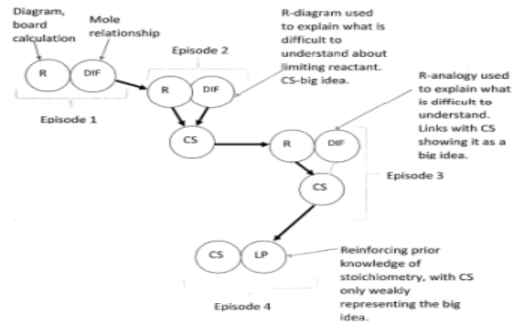
CCrosley

Carol Crosley
University Registrar
17th May 2015

Private Bag 3, WITS 2050, South Africa | T: +27 11 717 1201/2 | F: +27 11 717 1217 | E: registrar@wits.ac.za

Appendix 2. Comparison table between TSPCK episodes in planning and actual teaching of subsequent lessons of pre-service teachers.

Comparison between TSPCK episodes in planning and actual teaching

<table>
<tr><th>Participant</th><th>TSPCK episode in planning</th><th>TSPCK episode in actual teaching</th></tr>
<tr><td>Sipho</td><td>Lesson 1
Limiting reactants

</td><td>Lesson 1 – limiting reactants

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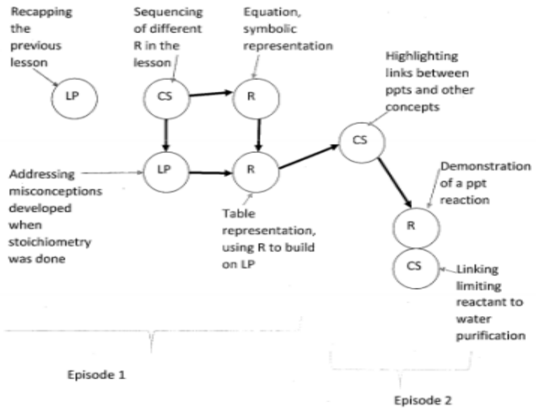
<tr><td></td><td>Lesson 2
Precipitation reactions and limiting reactants.

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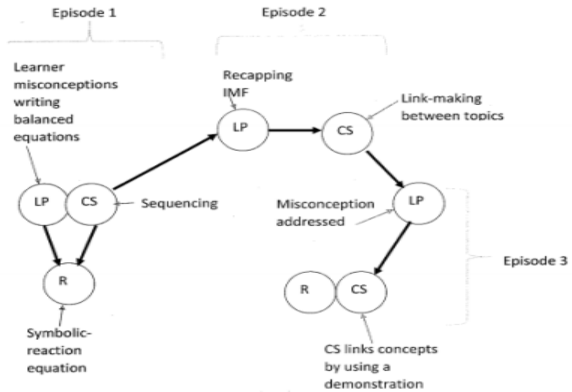
Precipitation reactions and limiting reactants

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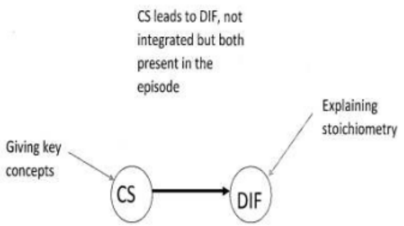
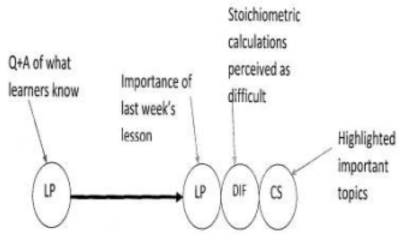
</table>

Jane

Stoichiometry
Lesson Plan 1
Introduction



Lesson1-stoichiometry



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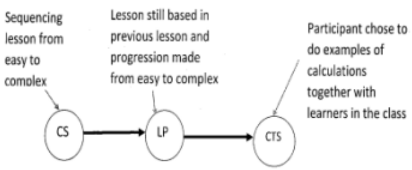
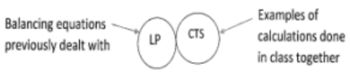
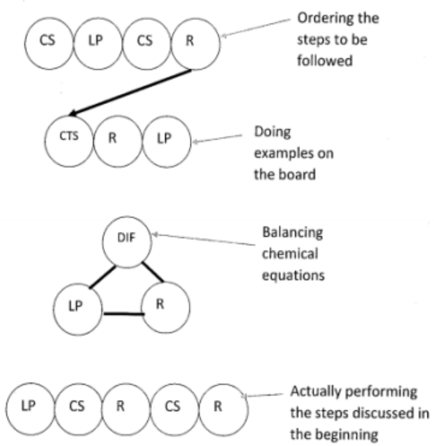


Episode 1

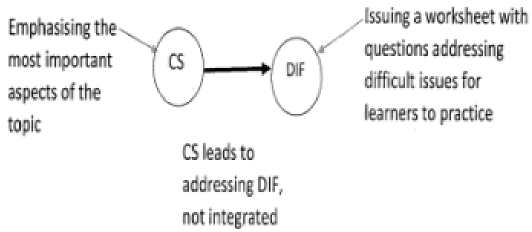


Episode 2

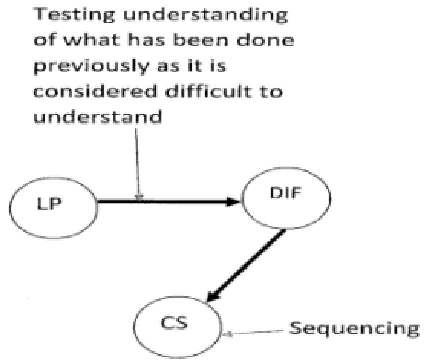
Body



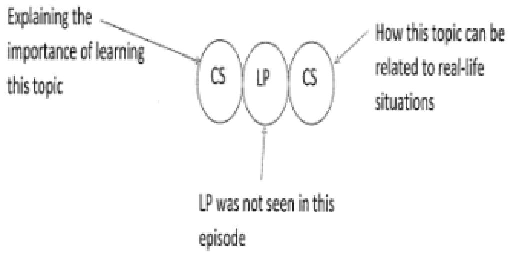
Conclusion



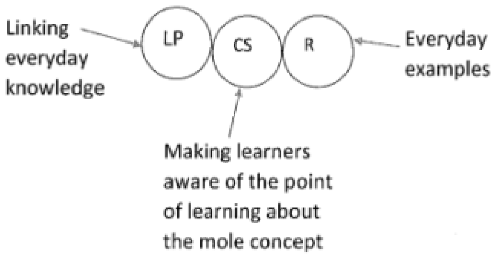
Conclusion



Lesson plan 2
Introduction



Lesson plan 2
Introduction



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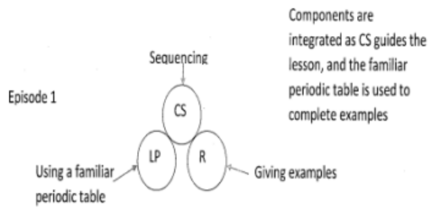

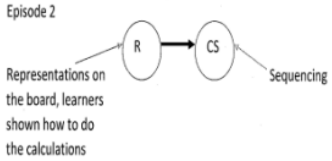

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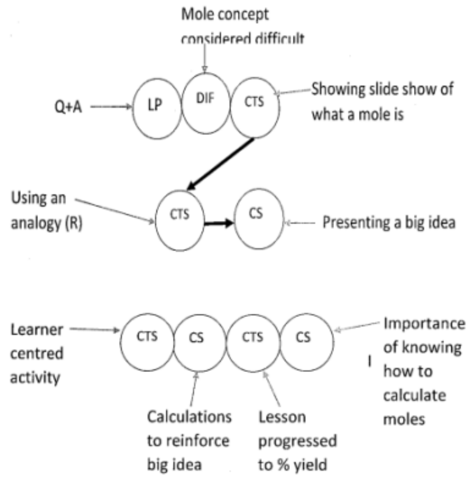
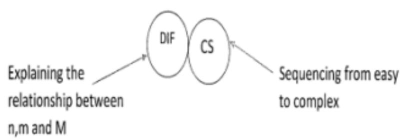
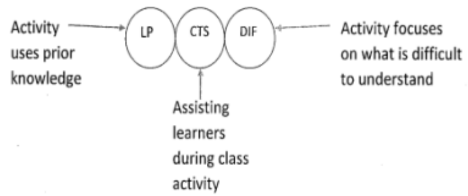


Conclusion

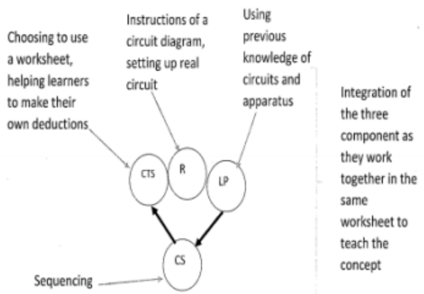


Conclusion

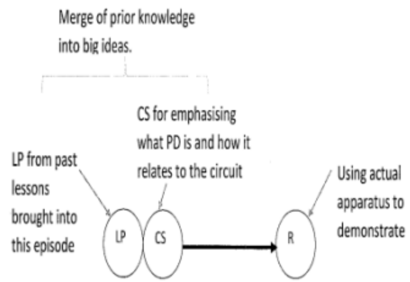


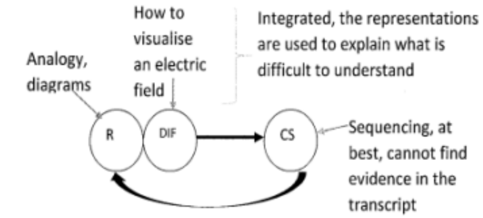
Buhle

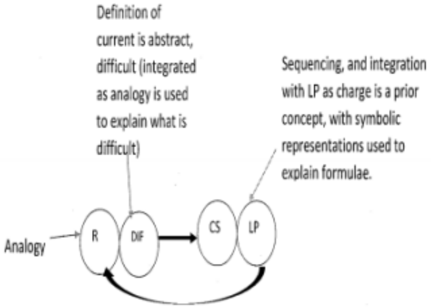
Lesson 1
Potential Difference and current

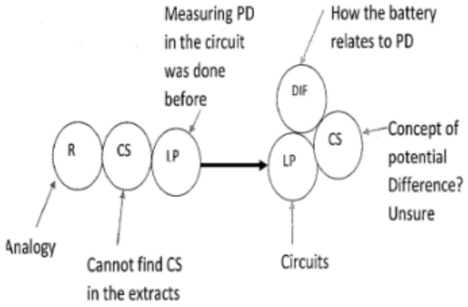


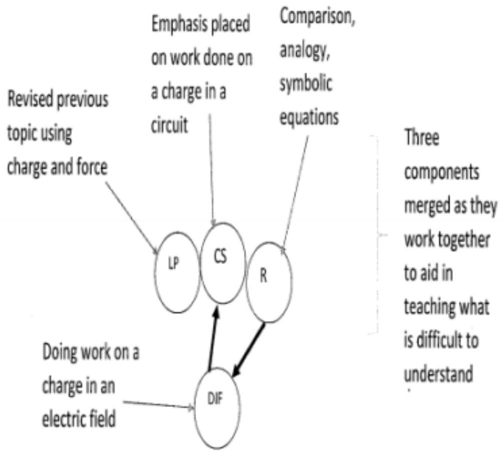
Lesson 1
Potential difference and current

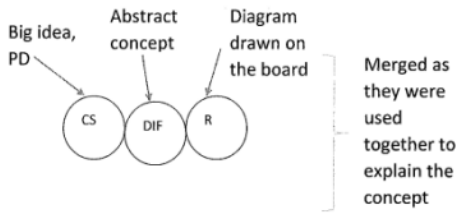


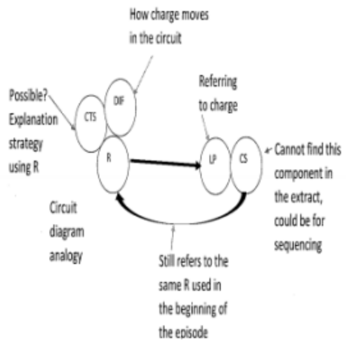

Analogy,
diagrams
How to
visualise
an electric
field
Integrated, the representations
are used to explain what is
difficult to understand
R
DIF
CS
Sequencing, at
best, cannot find
evidence in the
transcript


Definition of
current is abstract,
difficult (integrated
as analogy is used
to explain what is
difficult)
Sequencing, and integration
with LP as charge is a prior
concept, with symbolic
representations used to
explain formulae.
Analogy
R
DIF
CS
LP

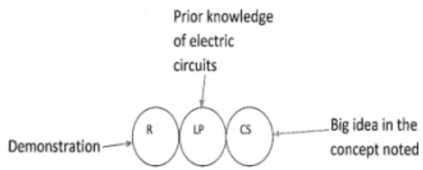

Measuring PD
in the circuit
was done
before
How the battery
relates to PD
DIF
CS
Concept of
potential
Difference?
Unsure
R
CS
LP
LP
Analogy
Cannot find CS
in the extracts
Circuits

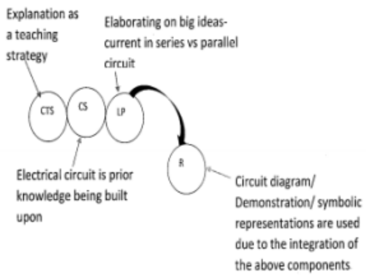

Emphasis placed
on work done on
a charge in a
circuit
Comparison,
analogy,
symbolic
equations
Revised previous
topic using
charge and force
Three
components
merged as they
work together
to aid in
teaching what
is difficult to
understand
LP
CS
R
Doing work on a
charge in an
electric field
DIF



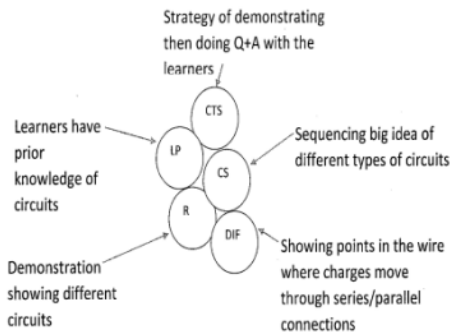


Lesson 2
Series and parallel circuit





Lesson 2
Parallel and series circuit



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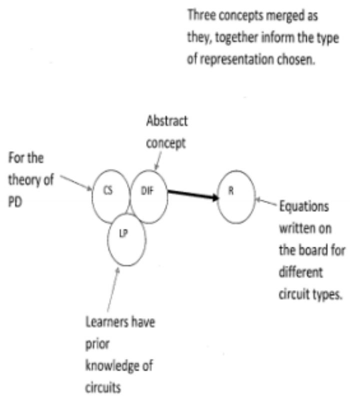
<tr><td></td><td></td><td>
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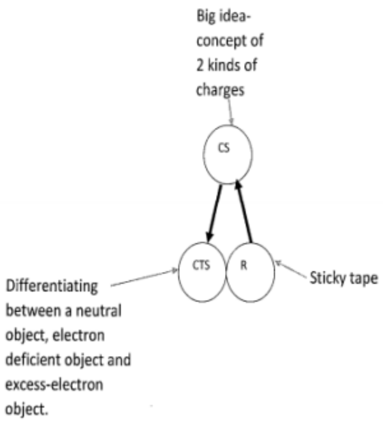
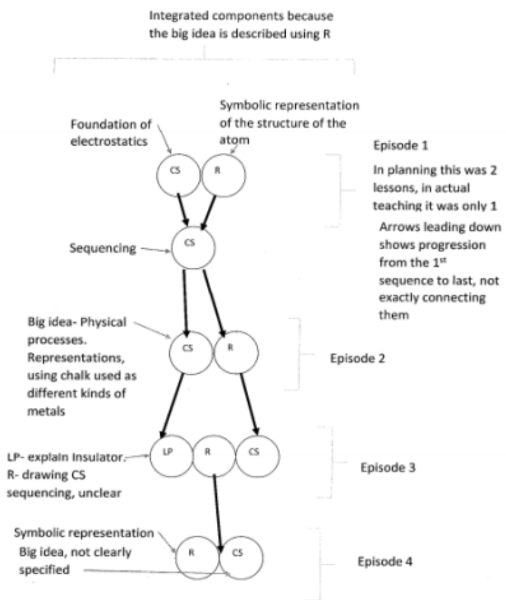
<tr><td>Zandi</td><td>Lesson 1
Two kinds of charges

</td><td>
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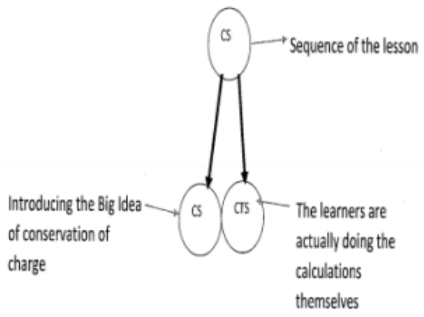
	Lesson 2 Conservation of charges 	Lesson 2 Conservation of charges This lesson was integrated into lesson 1 during teaching.

Appendix 3. Teacher belief rubric, adapted from Luft and Roehrig (2007)

1. How can you increase chances for student learning in your science classroom?					
Teacher focused				Student focused	
Traditional Teacher provides information in a structured environment.	**Instructive** Teacher monitors student actions during teaching	**Transitional** Teacher creates a classroom environment that involves the student		**Responsive** Teacher designs the classroom environment to enable students to interact with each other and their knowledge.	**Reform-based** Teacher depends upon student responses to design an environment open to individualised learning
• "By carefully planning my lessons" • "By using PowerPoint presentations" • "By arranging the classroom so that the students face me" • "I use a textbook, a study guide and we have it on the web"	• "By looking at students' responses" • "I watch my students closely as they complete lab activities"	**Cognitive** • "By using different types of activities" • "By encouraging them to do their own thinking"	**Affective** • "By building a positive, supportive environment" • "By having a relationship with students outside of class"	• "By using small group activities in which students hypothesise, predict, create, share and question" • "By giving students the opportunities to defend their ideas in front of their peers"	• "Knowing that not all students learn in the same way, I need to organise the lesson in different ways" • "By allowing students to choose their own vehicles to learn by"
2. Describe how you perceive your role as a science teacher?					
Teacher focused				Student focused	
Traditional Focus on information and structure	**Instructive** Focus on providing experiences	**Transitional** Focus on teacher/student relationships or student understanding		**Responsive** Focus on collaboration between teacher and student	**Reform-based** Focus on mediating student prior knowledge and the knowledge of the discipline
• "All knowing sage." • "Deliverer of information" • "I need to provide consistent routines and classroom rules"	• "To provide materials and opportunities for students to learn" • "I maintain student focus to minimise	**Student** • "I need to develop a good rapport with my students" • "You have got to make the students feel comfortable or	**Content** • "To guide the students in developing conceptual understanding and critical thinking skills"	• "To set up my classroom so that my students can take charge of their own learning"	• "I am a tour guide who helps students make sense of their surroundings in a manner that is consistent with what is known"

	management issues”	they will have a difficult time learning”			
3. During your school teaching experience, how did you know when your students understood what you taught them?					
Teacher focused				Student focused	
Traditional When they receive the information	**Instructive** When they can reiterate or demonstrate what has been presented	**Transitional** When they give an explanation or response that is related to the presented information		**Responsive** When they can utilise the presented knowledge	**Reform-based** When they can apply knowledge in a novel setting, related to the knowledge
• “It is important that they hear it three times” • “We covered it in class” • “When we cover the lesson in different ways”	• “When they can do well on a practical examination” • When they can use their own words to explain a concept” • “When they can repeat the answer correctly on a written test”	**Knowledge** • “When they talk about the presented knowledge in new ways” • “When they can ask a basic student-question during a presentation”	**Affective** • “Their faces light up” • “They get excited” • “When they are animated about the lesson outside of class”	• “When they can clearly defend their ideas using evidence and examples they experienced” • “When they can discuss new phenomena that they encounter in class”	• “They can come up with questions or comments representing understanding, using the knowledge in a new situation that was not experienced in the class” • “When students can question and dialogue in a manner that expands their understanding.
4. In a school setting, how do you decide what to teach and what not to teach?					
Teacher focused				Student focused	
Traditional Decision guided by adopted curriculum or other school factor	**Instructive** Decision based on teacher focus/direction	**Transitional** Decision in which some modification is based on student feedback		**Responsive** Decision based on student feedback and other possible factors	**Reform-based** Decision based upon student focus and guiding documents (eg., standards, research)
• “Based on time” • “Strictly by the book” • “Limited by the district curriculum”	• “What I enjoy and get excited about” • “What I feel comfortable with” • “If I have materials available”	• “What I think the students will be interested in” • “I think of the ability levels of my students”		• “What misconceptions students at this age have, and what the interests of my students are” • “Based on the knowledge and	• “The content/concepts have to be cognitively appropriate for the students and aligned with aspects of the standards”

			interests of my students and myself"	
5. How do you decide when to move on to a new topic in your classroom?				
Teacher focused			Student focused	
Traditional Directed by the teacher	**Instructive** Directed by teacher, based on basic student understanding of facts and concepts	**Transitional** Teacher decision based on limited student feedback or ability of the teacher	**Responsive** Decision based on student feedback that potentially involves revisiting concepts	**Reform-based** Decision based upon an ongoing evaluation of students' abilities to demonstrate understanding in different ways. May involve the modification of lessons
• "When the unit is over" • "When we have covered the material" • "When we run out of time"	• "Students can explain the contentl to me in their own terms" • "When I feel that the students get it" • "I give quizzes once a week to determine what my students know"	• "I can see them doing the lab work correctly" • "When the students use the ideas in class" • "It is not that the students got bored, but we covered it in as many ways as I could"	• "When students are comfortable with the content, they use it in their, writing and discussions" • "I move on when there is a lull, but if they start asking questions about the old idea, I go back"	• "An informal evaluation of student conversation and their work throughout the topic." • "When the students are applying the concepts to new situations and asking questions about the concepts"
6. How do your students learn science best?				
Teacher focused			Student focused	
Traditional From the teacher	**Instructive** By mimicking the teacher	**Transitional** By using procedures/guidelines	**Responsive** By encountering and interpreting phenomena	**Reform-based** By eliciting, encountering, and constructing their ideas about phenomena
• "By paying attention" • "By taking good notes"	• "By working problems we practiced in class" • "I show them what they need to do, then they look/do it by themselves"	• "By doing a lab practical" • "By doing hands-on activities"	• " They are challenged to create their own understanding to explain their generated idea" • "When they interact with one another as they try	• "When they have ownership over what they learn and how they choose to go about learning it." • "They all learn differently, but they need rich experiences which allows each

	• "They watch me do it, then they practice on each other"			to explain their results."	student to explore their notions of the experience and make sense of it in a new way"
7. How do you know when learning is occurring in your science classroom?					
Teacher focused				Student focused	
Traditional Determined by action of the students during instruction. Emphasis is on order and attention as related to the student.	**Instructive** Determined through measures given by the teacher. Emphasis is on the correctness of the student responses to the measure.	**Transitional** Determined through subjective conclusions about the student.		**Responsive** Students' interact with their peers or the teacher about a topic. Responses are limited or preliminary.	**Reform-based** Students initiate significant interactions with one another and/or the teacher about the topic.
• "It is still quiet at the end of the lesson" • "When they are paying close attention to the lesson"	• "I give quizzes to see if they are getting it" • "When they can follow the instructions in the laboratory" • "I look at their write-ups, graphs and tests"	**Cognitive** • "The students are actively engaged in learning, not passively learning" • "The students write a reflection about their learning"	**Affective** • "It gets noisy" • "I can tell by the look in their eyes" • "Talk about science outside of the class"	• "When students interact to solve problems" • "When students are helping each other" • "Students defend their ideas through the use of evidence and examples"	• "Students can formulate thoughtful questions about the content" • "Students seek their peers opinions about the content" • "When students are challenging one another"