THE DEVELOPMENT OF TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE IN OUT-OF-FIELD NATURAL SCIENCES TEACHERS IN A RURAL CONTEXT

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A Thesis Submitted to the Faculty of Humanities, University of Witwatersrand, in fulfilment of the requirements for the degree of Doctor of Philosophy

Johannesburg, South Africa

2020

DECLARATION

I declare that this thesis is my own work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at other University.

(Signature of candidate)

16th day of November 2020

ABSTRACT

In many countries, there are instances where teachers are teaching content at a level for which they are not qualified. This phenomenon is called teaching 'out-of-field' (OOF). OOF teaching is a common occurrence in low socioeconomic environments, especially in rural areas. However, the practice of OOF teaching remains under-studied and under-researched. There are a great number of complexities necessitating, for example, high attrition rates of qualified science graduate teachers in rural areas as a result of migration to urban areas, resource allocation, and absorption of science graduates into industries. More commonly, Junior Secondary Schools in rural areas are left with no choice but to appoint teachers out-of-their field of expertise.

This study was aimed at improving the teaching of Natural Sciences teachers who were teaching OOF at Junior Secondary level in the rural Eastern Cape. The theoretical framework was based on Pedagogical Content Knowledge (PCK), which explains how teachers transform content knowledge into a teachable form. PCK can be studied at several different levels; domain, subject and topic. The level of PCK studied for this study was Topic Specific Pedagogical Content Knowledge (TSPCK). Validated TSPCK and content knowledge instruments in the topic of particulate nature of matter were used to test content knowledge and quality of teachers' TSPCK before and after an intervention was carried out. The intervention was targeted at improving the quality of teachers' TSPCK in the topic of intervention and consequently their content knowledge. The TSPCK instruments completed by teachers before and after the intervention were scored using a criterion-based rubric. The quality of enacted TSPCK (eTSPCK) before and after the intervention was measured through qualitative in-depth analysis for TSPCK episodes displayed in teachers' video-recorded lessons. The identified teaching segments containing TSPCK episodes were then subjected to a rubric for analyzing eTSPCK. TSPCK scores generated by rubrics for both TSPCK and eTSPCK had inter-rater reliability 0.86 and 0.84 respectively. The results of this study have revealed an improvement in the CK, PCK and the ePCK of teachers in the topic of the particulate nature of matter. This finding provides a path for improving the effectiveness for teachers who face the challenge of out of field teaching.

Key Words: Out-of-field teaching, Pedagogical Content Knowledge, Topic specific Pedagogical Content Knowledge, Natural Sciences, Junior Secondary Level, Rural areas, the Particulate nature of matter

DEDICATION

This work is dedicated to my late grandmother Regina Nomatu Vokwana and my father, Siphiwo Vokwana for their tough love, which taught me to be strong, resilient and independent in life. My mother, Thobeka Vokwana, my late aunt, Priscilla Shasha and my beautiful sisters, Bamanye and Sesethu for their love, kindness and support, you are everything to me, thank you. My husband, Sindile Kaba for his patience and unwavering support to the end (I could have drowned in the shallow waters). Lastly, my daughter Akhani Nazizibele Kaba and my niece Lulu Vokwana, may you learn one thing or two from this piece of work.

ACKNOWLEDGEMENTS

I would like to acknowledge my supervisor Professor Elizabeth Mavhunga firstly for believing in me. I have only managed to complete this study because you have always encouraged me to be the best version of myself. Without your outstanding and intensive supervision and quality feedback, there would be no thesis. You have become my mentor from whom I have learnt more than just research skills but a correct attitude towards life in general, bravery, commitment and resilience. Your expertise in the essence of my work has had an invaluable impact on my career at large.

Professor Marissa Rollnick, God has particularly used you. I would not have had the opportunity to fulfil my dreams and passion in education if it was not for you. You have been there since the beginning of my journey from Masters, Sasol Inzalo Scholarship through PhD; your expertise and humility is a blessing to our country and the world at large. Thank you for believing in me, having you as my co-supervisor is a privilege.

Professor Bette Davidowitz thank you very much, I do not have enough words to express the amount of effort which you have put in developing and fast-tracking my experience in the science education field, I feel honored and blessed to have had an opportunity to be supervised by one of the big giants of science education in our country.

My deep appreciation to Sasol Inzalo scholarship, without whose generous funding, I would not be where I am and have the experiences I have had during my study. Through Sasol Inzalo I have attended two international conferences, SAARMSTE in Botswana and ESERA in DCU-Dublin Ireland. The feedback and interactions from leading scholars and researchers in science education around the world played a significant role in the completion of this study. Your efforts and dedication in developing academics are beyond generosity. Additionally, I would like to acknowledge the University of Fort Hare for assistance with study subsidy grants and unwavering academic support that I have received from the Teaching and Learning Centre. When Sasol Inzalo could no longer fund my studies the University of Fort Hare took over to make sure that this study was completed. The Swana family (Professor and Dr Swana) and Mrs. Arosi, God has especially used you, your contribution and support in this study will be forever cherished, thank you for welcoming me into your families as one of your children; your prayers have kept me going. I also thank the fifteen NS teachers who made availed themselves willingly and participated in this study. I would have never completed this study without you. Furthermore, the three teachers who welcomed me into their classes, thank you so much. Classroom teaching is a sensitive issue but you were brave enough to participate in this study against many odds. This was one of the challenging parts of my research but God carried me through it all, “Now to Him who is able to do exceedingly abundantly above all that we ask or think, according to the power that worketh in us, unto Him be glory Forever and ever.”

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ABBREVIATIONS

BEd	Bachelor of Education
CAPS	Continuous and Assessment Policy and Statement
CK	Content Knowledge
CM	Consensus Model
CoRe	Content Representations
cPCK	Collective Pedagogical Content Knowledge
CPD	Continuous Professional Development
CS	Curricular Saliency
CT	Conceptual Teaching Strategies
DBE	Department of Basic Education
ECDBE	Eastern Cape Department of Basic Education
ePCK	Enacted Pedagogical Content Knowledge
eTSPCK	Enacted Topic-Specific Pedagogical Content Knowledge
FET	Further Education Training
GET	General Education Training
JPTD	Junior Primary Teachers' Diploma
LMS	Learning Management System
LP	Learner Prior Knowledge
MM	Mixed Methods
NPDE	National Professional Diploma in Education
NS	Natural Sciences
OFTs	Out-of-field teachers
OOF	Out-of-field
PCK	Pedagogical Content Knowledge
PDI	Professional Development Intervention
PNOM	Particulate Nature of Matter
pPCK	Personal Pedagogical Content Knowledge
PTC	Primary Teacher's Certificate
PTC	Pedagogical Transformation Competence
RCM	Revised Consensus Model

REQV	Relative Education Qualification Value
RP	Representations
RQ	Research Question
SMS	Short Message System
SPTD	Senior Primary Teachers' Diploma
STD	Secondary Teachers' Diploma
STEM	Science, Technology, Engineering and Mathematics
TPDP	Teacher Professional Development Programme
TSPCK	Topic Specific Pedagogical Content Knowledge
WD	What is difficult to teach

CHAPTER 1

INTRODUCTION TO THE STUDY

This study reports on the impact of Topic-Specific Knowledge for teaching the particulate nature of matter on the quality of content knowledge, TSPCK and eTSPCK for out of field Natural Sciences Teachers in the rural Eastern Cape. In this chapter, a brief introductory description of the study is given. This chapter also gives the rationale, problem statement for the study highlighting the purpose, context, research questions and background of the researcher who conducted the study. The chapter is closed with an outline of this thesis.

1.1. Introduction

The history of South Africa presents a story of a divided education system. Before 1994 education was used to control political, social, and economic development. The government policies of the day sought to promote separate development which was intended not only to divide the citizenry along racial lines but also the country's geography into urban, peri-urban and rural areas. Rural areas were characterised by the poor quality of education, particularly science education, low levels of literacy, lack of facilities and poor infrastructure (Masinire, Maringe & Nkambule, 2014). The quality of education was tampered with to ensure poor quality provision for the African population group (Skovsmose, 2005).

Widespread effects of this segregated education policy continue to trouble the present society. Poorly trained personnel from the pre-1994 dispensation is part of the democratic era practising as teachers, nurses and others. The government of South Africa claims improvement in the access of education since the dawn of democracy, but there is still more to be done. According to the 2019 National Senior Certificate (NSC) examination report, physical science is one of the gateway subjects that have seen a tremendous decline in student enrolment for the subject (DBE, 2020). The education-related challenges continue to trouble rural areas especially in the Science, Technology, Engineering and Mathematics (STEM) subjects. As a result of this, the Eastern Cape is one of the top two provinces which have contributed largely to the decline rate in the physical science student enrolments for 2019 examination following after the Limpopo (DBE, 2020).

The rural schools have always been synonymous with lack of resources, poor infrastructure and difficulty to recruit and retain qualified teachers (Du Plessis, Gillies, & Carroll, 2014). In 2015, there were about 11 252 rural schools across the country that account for nearly half of South Africa's estimate of 25 000 schools and most of these rural schools were located in the Eastern Cape, KwaZulu Natal and Limpopo (Macupe, 2018). The difficulty to staff classrooms with suitable teachers in the rural areas might to some extent contribute to the broader question of the decline in students choosing STEM subjects across the world and might lead to a decline of graduates in the STEM careers (Freeman, Marginson, & Tytler, 2014). This development is contrary to the needs of the fourth industrial revolution, which requires highly competent graduates in the STEM areas. Among educational complexities in the rural areas is the poor content knowledge of teachers (Masinire et al, 2014). Literature shows that there are strong interrelations between student academic achievement and the quality of teachers and their teaching thereof (Zhang, Parker, Koehler, & Eberhardt, 2015). Thus, exploring various options for teacher development and quality improvement especially in content areas such as physical science education and mathematics should be of high priority.

The study seeks to improve TSPCK of teachers who are teaching chemistry with no background knowledge in physical science. In South Africa, Natural Sciences (NS) is a science subject taught at the intermediate phase and senior phase, which is (Grade 4-9). NS is a blend of aspects of Life Science and Physical Science. At the senior phase, the Curriculum and Assessment Policy Statement (CAPS) presents Natural Sciences as a subject meant to:

> "….lay the basis of further studies in more science-specific disciplines such as life sciences, physical science, earth science or agricultural sciences"(DBE, 2011, p. 11).

The subject, therefore ideally requires good content knowledge across various disciplines. This study, however, explores knowledge of a topic in physical science. Previous research studies indicate success in using the TSPCK construct (Mavhunga & Rollnick, 2013) and the PCK construct (van Driel & Gräber, 2002) in improving the knowledge for teaching specific physical science topics with pre-service teachers. However, little is known about success in applying the construct with teachers practising out of their field of expertise (referred to hereafter as 'OFTs').

1.2 Rationale

Out of field teaching has dire implications for classroom practice (such as perpetuating poor-quality teaching and learning). There is a critical shortage of qualified teachers in rural areas (du Plessis & Mestry, 2019). Du Plessis and Mestry (2019) elaborate on the lack of qualified teachers in rural areas, stating that one of the challenges is that many teachers in rural schools were not properly trained and were unfamiliar with the latest trends in teaching methods. In the TIMSS 2015 report, about 79% of mathematics teachers had content knowledge levels below the level at which they were teaching. There are suggestions that the introduction of teacher professional standards might improve the quality and professionalism of teaching across the country (Maphosa, Mutekwe, Machingambi, Wadesango, & Ndofirepi, 2012). The poor infrastructure is not helping either because according to Gardiner (2008) teachers travel an average of 36 km and more per day to school, which means that rural teachers spend fewer hours in classrooms due to the long distances they travel daily. The distance problem often further impedes attendance to organized teacher development initiatives thus missing opportunities to interact with other teachers to improve their practice. Du Plessis and Mestry (2019) stated that teachers in rural areas had limited access to in-service training or support from the provincial departments of education.

According to Kriek and Grayson (2009), the quality of schools depends on teachers irrespective of the background and context of the school, and therefore to have continuous sustainable education reforms especially in maths and science, strengthening the quality of teachers becomes vital.

It is for this reason that this study seeks to improve not only Topic-Specific Pedagogical Content Knowledge and consequently content knowledge but also to possibly offer a model for effective teacher professional development. Shulman (1986) identified content knowledge as a requirement that teachers should possess in the relevant subjects which they are teaching. In particular, Shulman (1986) defines teaching as requiring transformation of content knowledge for effective teaching, suggesting that possession of content knowledge alone is not sufficient for teaching. According to Nilsson and Loughran (2012), qualified teachers develop their PCK in practice. In a study by Chan and Yung (2018), it is indicated that even qualified practising teachers continue to develop their PCK in practice especially when faced with teaching a new topic. Out-of-field teachers thus have the double task of developing both their content and PCK in the topics they teach in practice. This is a daunting task that requires innovative ways of improving content and PCK simultaneously. A study by Mavhunga (2014) demonstrated that there is a possible way of fast-tracking pre-service teachers' expertise in TSPCK and content knowledge in chemical equilibrium by explicitly making the transformation of content knowledge in a teacher preparation programme. The possibility of using TSPCK for the same purpose in a specific topic has not been explored with teachers practicing out-of-field of expertise. Thus, this study aims at contributing to this knowledge gap in the literature and possibly provide a feasible model for professional development programmes suitable for improving content knowledge and TSPCK and eTSPCK of out-of-field science teachers in South Africa.

1.3 Problem Statement

The current state of rural education is detrimental to South Africa as a nation. If left unattended, this has future connotations involving generations of rural learners with poor quality results in STEM subjects. This will exclude them from higher education learning and there will be generations who drop science immediately when they are presented with options and thus cause intergenerational poverty. Teachers in rural areas face many challenges that are unique to their context and such challenges include poor infrastructure and facilities, curriculum challenges, the unattractiveness of the rural schools and underqualified teachers, to mention few. This is an indication that for rural schools to improve rural teachers need to be equipped with ways of dealing with educational challenges within their context. Therefore, the models of development for such teachers ought to be contextual, and considerate of the circumstances under which these teachers are practising.

In this study, the focus was on the teaching of science because if not addressed, the existing conditions such as lack of skills, poverty and minimal hope for progress in rural areas could persist. Monk (2007) argues that attainment of economic growth in rural areas might be successful if issues such as low teacher qualifications, teaching in fields out of teacher's areas of training and lack of diversity among teachers can be foci instead of general policies. Since current teachers teaching in these conditions cannot be automatically replaced, there is a need to develop and support them to raise the quality of content knowledge and conceptual teaching strategies. This study seeks to improve the TSPCK and subsequently content knowledge for teachers who are teaching chemistry with no background knowledge of physical science in the rural areas of Eastern Cape.

1.4 Background of the researcher

The researcher completed a BSc in Chemistry in 2008 and a BSc Honours degree in 2009, both at the University of the Western Cape. She went to work for PetroSA's refinery plant in 2010 and the year she spent at PetroSA made her realise that her heart was in education and that she wanted to give back to the community, especially in rural areas. At the SACI conference that was held at Wits University in January 2011, she was put in touch with Associate Professor Bette Davidowitz who became her supervisor in February 2011 when she registered at UCT for an MSc in Chemistry Education. She found organic chemistry to be one of the most difficult topics if it is not taught carefully. she then joined the PCK (Pedagogical Content Knowledge) project that had its headquarters at the

University of the Witwatersrand. The study at the University of Cape Town designed an instrument to assess grade 12 teachers' Topic-Specific PCK in organic chemistry and therefore got a glimpse of how teachers transformed their content knowledge for teaching organic chemistry at the Grade 12 level. After completing her studies with the University of Cape Town, she spent almost two years with Axium Education (NGO) in the deep rural areas of Mqanduli assisting both science teachers and learners with Physical Sciences and facilitating science teacher Networks in at least five local high schools. This is where she learnt the multi-faceted complexities of rural schools in the Eastern Cape, particularly the practice of out-of-field teaching. The researcher joined the University of Witwatersrand for a full-time PhD in chemistry education through Sasol Inzalo Scholarship under the supervision of Professor Elizabeth Mavhunga and Professor Marissa Rollnick in education. She is passionate about rural education and my dream is to expand this study beyond a requirement for PhD and disseminate the findings through professional development interventions for out-of-field science teachers in the rural areas.

1.5. The context of the study

About 39% of science teachers in South Africa are teaching out of their field of training (du Plessis, Gillies, & Carroll, 2014; Silva, 2010). There are implications on such teachers as described above which include weak content knowledge, little confidence on the content they are teaching, abstract conceptual teaching strategies and these could perpetuate poor quality of teaching and learning. Luft, Hill, Weeks, Raven, and Nixon (2013) argue that the problem of teachers teaching out of their field of expertise is persistent in the middle school level, especially in developing countries suggesting that this is a global practice. While this is a worldwide practice, such a practise might not be a problem in countries where the quality of education is quite high as teachers might fall back on their established content knowledge. However, in a country faced with poorly prepared teachers, such teachers might not have sufficient knowledge needed to handle science topics in both their planning and teaching. Thus, science education researchers have a moral obligation to research innovative ways to close the existing teacher qualification knowledge gap in out-of-field teaching.

In this study, Natural Sciences Teachers practising out of their field of expertise in the rural areas of the Eastern Cape were participants. These teachers were qualified as Primary school teachers but were teaching in Junior Secondary Schools that had an intake of from Grade R to Grade 9. These schools are an inheritance of pre-1994 dispensation. In the democratic era, schools have an intake of Grade R-7 classified as primary schooling and Grades 8 – 12 as high schools. The primary school teachers in this study were teaching Grades 8 and 9 and these are high school grades. Moreover, these teachers had no chemistry background.

1.6 The research questions

The overall purpose of this study was to improve TSPCK, eTSPCK and consequently content knowledge of OFTs by exposing them to an intervention with an explicit focus on the construct of TSPCK, unpacking the construct and re-building it for learning to teach the topic – the particulate nature of matter. To understand the impact of the intervention in improving TSPCK, eTSPCK and content knowledge of out-of-field teachers, the main research question was framed as follows:

'What is the impact of an intervention with an explicit focus on TSPCK on the quality of teacher knowledge and classroom practice of out-of-field Natural Sciences Teachers teaching in rural areas?'

There is growing evidence in the literature for understanding content knowledge from the perspective of knowledge for teaching the subject such as the 'specialized content knowledge' (SCK) in mathematics education (Ball, Thames, & Phelps, 2008). This implies teaching content knowledge to prospective and practicing practising teachers in the manner that they would be expected to think about the teaching particular content. Many studies on PCK acknowledge content knowledge as a precursor to the development of PCK. To establish this impact, a measuring CK tool designed and validated to measure teachers' content knowledge in the particulate nature of matter was used before and after the intervention. The following sub-question was formulated for this purpose:

1. **What is the impact of the intervention on OFTs' content knowledge in the topic of the particulate nature of matter?**

The study acknowledges the development of PCK at both planning to teach context which will be referred hereafter as TSPCK and real classroom teaching which is called enacted eTSPCK. This acknowledgement led to the second and third research questions. To study the impact of the intervention in improving the quality of TSPCK and eTSPCK in the particulate nature of matter the following two sub-questions were formulated:

2. **What impact does the intervention have on the quality of OFTs' TSPCK in the topic of the particulate nature of matter?**
3. **What impact does the intervention have on the quality of OFTs' eTSPCK in the topic of the particulate nature of matter?**

1.7 Overview of the research design of the study

In this study, the aim was to improve the situation with out-of-field science teachers who were teaching Natural Sciences in the rural Eastern Cape. Several studies have reported success in developing the Topic-Specific knowledge for teaching science topics (Mavhunga & Rollnick, 2013; Pitjeng-Mosabala & Rollnick 2018). These studies have also indicated that success in improving Topic-Specific knowledge for teaching science topics also improved content knowledge. Thus, TSPCK was adopted as the framework of the study (see chapter 2 for detail). The PCK construct including TSPCK is based on the hypothesis that teachers require a reasonable level of CK to be able to develop PCK in a specific topic. PCK in science education research emphasized understanding of PCK holistically in two levels which are planning to teach context and actual enactment in the classroom (Aydeniz & Kirbulut, 2011). Thus, in this study, an intervention that exposed out-of-field teachers to Topic-Specific knowledge for teaching the particulate nature of matter was conducted to improve TSPCK at both levels referred to in this study as TSPCK and eTSPCK as well as their content knowledge. (See chapter 4 for detail about intervention).

To assess the impact of the intervention to improve TSPCK of the OFTs in the particulate nature of matter, a validated TSPCK instrument was modified and administered before and after the intervention. This instrument was used to access the Topic Specific PCK of out-of-field Natural Sciences teachers in the particulate nature of matter as well as their level of understanding of the concepts which are taught to learners at Junior Secondary level before and after the intervention (see chapter 3 for detail). The tasks were designed similarly to those in a standard test of concepts in the particulate nature of matter. The instrument to evaluate the teachers' TSPCK is based on the categories of Topic-Specific PCK model of Mavhunga and Rollnick (2013) (see Chapter 3). Both quantitative and qualitative analysis were conducted to analyse data (see chapters 5 and 6 for detail). The CK data were scored using a memorandum (see Appendix 6) according to the responses which teachers gave to the questions posed. A rubric was used to assign scores from 1 (limited response) to 4 (exemplary response) to the open-ended responses which teachers gave in the TSPCK tool (see Appendix 4). The rubric yielded numeric clusters which were subjected to Rasch analysis, and the details of how these were analysed will be provided in chapter 5 and 6. In capturing the enacted PCK of out-of-field teachers in the topic of intervention, video-recorded lessons of teachers were observed before and after the intervention. In-depth qualitative analysis was conducted to understand emerging patterns from this data in relation to answering research question on the impact on enacted PCK in the topic of intervention (see chapter 7 for detail). The findings will be presented in chapter 8.

1. 8 Thesis Outline

This thesis consists of eight chapters:

Chapter 1 provides a brief description that is used to guide the study in this chapter. An introduction to the study, the rationale, context, problem statement, accompanying research questions and a brief description of the research design is provided.

Chapter 2 provides the literature reviewed as the framework of this study. In this chapter, the construct of Topic-Specific PCK as developed by Mavhunga and Rollnick (2013) is considered. The components of TSPCK that transform CK and includes other models that form part of the Mavhunga model.

Chapter 3 discusses the methodology and reasons for the choice of the methodology followed to collect and analyse data, and how the research was conducted using mixed methods. The chapter also describes the modification of TSPCK instruments and ethical issues related to the study.

Chapter 4 discusses the design of the intervention for out-of-field teachers. The knowledge construct that is used in the intervention, as well as core features of teacher professional development, is described.

Chapter 5 presents data analysis and how CK instruments are scored. This chapter responds to the first research question.

Chapter 6 describes the data analysis and explains how the TSPCK instruments are scored using the presented rubric. The qualitative analysis interpreting patterns emerging from data are presented. Evidence is provided to answer the second research question.

Chapter 7 presents in-depth qualitative data from video-recorded lessons providing answers to the third research question on enacted PCK in the topic of particle nature of matter.

Chapter 8 gives a brief discussion of the discussions, implications and recommendations followed by the list of my references and the appendices.

1.9 Definition of key concepts

1.9.1 Out of field teaching

Out of field (OOF) teaching is a common practice across the world. It is defined as a situation where teachers are placed to teach content areas out of field of expertise or out of phase of training. This occurrence is more prevalent in the low socio-economic areas such as rural areas. Out of field teachers are characterized by poor content knowledge and weaker pedagogical content knowledge. In chapter 2, a detailed discussion of the concept of out of field teaching is provided.

1.9.2 Pedagogical Content Knowledge

In 1986, Shulman described Pedagogical Content Knowledge (PCK), as the transformation of Content Knowledge into various forms which help students to understand the concepts. Shulman (1987) further identified the construct of PCK as one of the knowledge bases of teachers. There are various models of PCK that were developed by many researchers with the aim to characterize this transformation of Content Knowledge (CK) (Magnusson et al, 1999; Veal & McKinster, 1999; Mavhunga & Rollnick, 2013).

1.9.3 Topic Specific Pedagogical Content Knowledge

Mavhunga and Rollnick (2013) developed the construct of Topic Specific Pedagogical Content Knowledge (TSPCK) which was defined as the ability to transform the subject matter of a given topic for the purpose of teaching and learning purposes. The Mavhunga and Rollnick (2013) model of PCK was built upon, among others, the views of Geddis and Wood (1997). Geddis and Wood, (1997) argued that subject matter transformation being reasoned through a variety of knowledge components and these are: Learners' Prior Knowledge (LP), Curriculum Saliency (CS) (deciding what is important for teaching and sequencing) What makes a topic easy or difficult to understand and teach (WD), Representations including powerful examples and analogies (RP) and. Conceptual Teaching Strategies (CT).

1.9.4 Professional Development Programmes

Teacher Professional Development Programmes are common practice across the world. The PDPs that provides an on-going learning opportunity to teachers and is essential for teachers to be effective and successful in the classroom, (Hooker, 2008). These teacher learning-platforms focus on a set of knowledge and skill-building activities which enhance teachers' ability to respond to classroom challenges more efficiently (Sharplin, 2014).

1.9.5 Rural areas

In South Africa, specifically before 1994, the country was divided along racial lines and geography into urban, peri-urban and rural areas. Rural areas are characterised by poor quality of education and low levels of literacy, facilities and poor infrastructure.

1.9.6 Content Knowledge

Shulman (1986) used the term Content Knowledge (CK), to refer to the amount and organization of knowledge per se. According to Shulman (1986) CK, had three distinguishable categories and these were; subject matter knowledge, pedagogical knowledge and curriculum knowledge. He referred to CK as 'going beyond knowledge of the facts or concepts of a domain but further required comprehension of the structures of the subject matter' (Shulman, 1986). Shulman separated each of these categories and discussed them individually as knowledge categories needed teachers where CK content was used as an entity equivalent to subject matter knowledge only. Content Knowledge is the knowledge and understanding of the central concepts, factual information and organizing principles that make up a discipline an understanding of the big ideas (Grossman, Wilson, & Shulman, 1989).

1.9.7 Natural Sciences

Natural Sciences at the Senior Phase in South Africa is regarded as a learning area that lays foundation for further studies in more specific Science disciplines, such as Life Sciences, Physical Sciences, Earth Sciences or Agricultural Sciences. Natural Sciences is taught to prepare learners for economic activity and self-expression.

CHAPTER 2

LITERATURE REVIEW

One of the most important aspects of any academic project is a critical review of the relevant literature in the field of interest. Literature review ensures firm foundations for advancing knowledge by enlightening the researcher about areas in the field that have been thoroughly researched and uncover areas in the field that still need to be researched. The purpose of this study was to develop TSPCK for out-of-field teachers who are teaching Natural Sciences in a rural context. The teachers involved in this study are practicing teachers and it is understood that such teachers use Teacher Professional Development Programmes (TPDPs) to learn. Thus, in this chapter, a critical review is presented of relevant literature on teacher professional development programmes specifically for what they are, as well as the core features defining effective TPDPs. After was literature review on out-of-field teaching and what literature perceives as challenging in out-of-field teaching. Literature is presented on the difficulties about learning the particulate nature of matter in science. Finally, this chapter is brought together through the discussions of knowledge needed by science teachers in transforming their content knowledge. A full argument is made based on PCK and TSPCK as the professional knowledge for science teachers which is widely used to fast-track knowledge of science teachers with no pedagogical experience. The chapter is concluded by locating the study within the relevant literature as its conceptual framework and summary of the chapter.

2.1 Introduction

Shortage of qualified science teachers in South Africa is recognized as one of the various challenges facing science education in Africa at large (Ogunniyi & Rollnick, 2015). Such educational situations like teacher shortages are understood to be the central reason in most cases that lead to teachers being appointed to areas or levels for which they are not qualified (Sharplin, 2014). This situation is called 'out of field' teaching (referred to as OOF hereafter) (du Plessis, Gillies, & Carroll, 2014). OOF teaching has shown to have a negative effect on the quality of science instruction and constrains teachers' development (Nixon, Luft, & Ross, 2017). In a paper by Luft, Hill, Weeks, Raven, and Nixon (2013) out-of-field teaching causes teachers to lack content knowledge and adopt generalized instructional strategies when teaching and their approach to content is superficial.

According to Shulman (1986), one of the central features defining a science teacher is their content knowledge and pedagogical knowledge which is integrated for teaching to form professional knowledge needed to teach a specific topic. Shulman (1987) argued that there is a special kind of teacher knowledge that assists teachers to re-structure and transform their content understanding into versions that are easily understandable by learners. He referred to this kind of knowledge as PCK. However, research in PCK has led to the argument that when classroom teaching is planned for and observed, the level of PCK needed is Topic-Specific, called Topic Specific PCK (TSPCK) (Mavhunga & Rollnick, 2013). The construct of TSPCK has gained increasing popularity within teacher education institutions as a strategy to assist pre-service teachers to fast-track their knowledge for transforming content knowledge (Mavhunga, 2015).

Teacher professional development programmes are well known for offering in-service teachers a way of learning newly implemented curriculum reforms (Kunter, Kleickmann, Klusmann, & Richter, 2013). The main purpose of this study was to improve TSPCK of out-of-field science teachers who were teaching Natural Sciences in the rural Eastern Cape. TSPCK was used in the content of a TPDP and implemented in the study. The choice of TSPCK was well-known for its' positive influence in science teacher knowledge for developing teacher professional knowledge needed for teaching a specific topic. The particulate nature of matter was used as a topic of intervention due to the Topic-Specific nature of PCK. This topic is regarded as difficult to learn due to its abstract nature (Andersson, 1990). The particulate nature of matter is also considered as fundamental to understanding various topics in chemistry and is thus considered as a fundamental concept in chemistry (Gabel, Samuel, & Hunn, 1987). A literature review of out-of-field teaching, TPDPs and TSPCK are presented in the following sections.

2.2 Teaching out-of-field

Out-of-field teaching is defined as a situation where a teacher does not have an academic major or certification in the subject he or she teaches (Sharplin, 2014). This occurrence is common in schools located within low socioeconomic environments such as rural areas. Teaching out of the field of expertise and out of the phase of training is a common occurrence in poor areas such as rural context (du Plessis, 2019). There are suggestions that the quality of teaching in the Eastern Cape is poor (Spaull, 2013). One of the reasons for this poor quality teaching is the background of teachers which is poor in terms of content (Kriek & Grayson, 2009). The rural areas are left with teachers who are teaching out of their field of training due to difficulty in retaining properly qualified teachers.

According to Luft et al. (2013) one of the problems which have been identified in out-of-field teachers is that these teachers seem to possess less knowledge of the content out of their field. These teachers apply general instructional strategies and their approach to content tends to be superficial compared to teachers who would approach content confidently in their content which is in their field of training (Luft et al., 2013). Out-of-field teaching is not only a lack of content knowledge from the perspective expected of learner knowledge at a particular grade. Hobbs and Torner (2019) suggest that teacher specialisation in any specific field meant that one was on a learning path to get deeper insights and become expert in the knowledge and skills of that specific discipline. The knowledge and skills in a specific discipline enable content-specialised teachers with the capacity to make coherent explanations and to make flexible connections to what is known and what can be done in a specific topic. These are a set of knowledge and skills which OFTs were never exposed to. In science education, an expert teacher in a specific content area is defined by the ability to understand the curriculum content structure faced with, specifically the big ideas, and how these are sequenced and represented through conceptual teaching strategies to support student learning (Geddis & Wood, 1997; Hobbs & Torner, 2019). It is further argued that experience refines this knowledge and is evidenced through quality of teaching produced by experts (Shulman, 1986). It can be concluded that expertise in a specific field is defined by teachers' ability to understand its' contents and history along with the theories of practise in a specific content area that in return exposes one to best practises in the field.

The above-mentioned set of knowledge and skills are acquired through formal qualification in a specific discipline and further develop and grow through experience in practice in specific content. It is evident from the discussion above that what makes teachers to be categorized as specialist or non-specialist is the content they are teaching and the training they have received to qualify as teachers, and the match or mismatch between the two makes teachers in or out-of-fielders. It is commonly known that enhancing the content knowledge of teachers changes their confidence, their guidance of students' learning as well as classroom approaches (Hobbs & Torner, 2019).

du Plessis et al. (2014) argue that one of the options towards the genuineness of education is to provide out-of-field teachers with suitable professional development which puts their needs into perspective. There are two types of professional development, those looking at the needs of pre-service and those looking at in-service teachers. The in-service professional development is primarily intended for all types of practising teachers, newly assigned teachers, experts and those out-of-field, which makes that kind of training a 'one size fits all'. However, out-of-field teaching automatically generates a situation which exposes teachers to tricky teaching conditions and therefore such teachers have special developmental needs. Du Plessis et al. (2014) and Zhang et al. (2015), argue that effective professional development for such teachers would only be meaningful and effective for development if such programmes are primarily aligned with these teachers experiences. Thus, in their research du Plessis et al. (2014) focused the real-life experiences of out-of-field teachers in terms of the meaning, perceptions and leaders' influence on out-of-field teachers' professional development. The findings of this study show that people working with out-of-field teachers had assumptions and misconceptions about out-of-field teachers and professional development for such teachers. For example, one school principal stated that he saw no need to send an out-of-field teacher to professional development programmes as he believed that this teacher was a short-term solution. This statement is ignoring the fact that the teacher was currently teaching nonetheless. Thus, in this study, focus was on the impact of an intervention with an explicit focus on TSPCK to improve quality of the OFTs' TSPCK, eTSPCK and subsequently content knowledge in the particulate nature of matter.

2.3 Teacher Professional Development Programmes (TPDPs)

Teacher Professional Development Programmes are a worldwide phenomenon that provides on-going learning opportunities to teachers and is essential for teachers to be effective and successful in the classroom (Hooker, 2008). These teacher learning-platforms focus on a set of knowledge and skill-building activities which enhance teachers' ability to respond to classroom challenges more efficiently (Sharplin, 2014).

Teaching as a profession need on-going learning at different stages of the teaching career to meet complex challenges and the ever-changing academic standards and goals (Nixon, Luft, & Ross, 2017; Petrie & McGee, 2012) to enhance their practice for students to receive quality learning. According to Hobbs (2013), there are different kinds of TPDPs designed to suit teachers' needs at their current stages of teaching which include different types of teacher learning communities at the in-service stage. The author argues that such platforms specifically target practicing teachers who are already assigned in schools ranging from district clusters or teachers' networks, collegial sharing and discourse, and teacher development programmes (Hobbs, 2013).

The development of Topic-Specific knowledge needed for classroom practice especially in science education is becoming a point of emphasis on TPDPs (Birman, Desimone, Porter, & Garet, 2000; Faulkner, Kenny, Campbell & Crisan, 2019). Such emphasis includes focusing on content knowledge coupled with opportunities for active learning. In addition, coherence of TPDPs with teachers' other professional development experiences and state and district standards are key aspects of in-service TPDPs (Zhang, Parker, Koehler, & Eberhardt, 2015). Faulkner, Kenny, Campbell and Crisan (2019) suggest that teacher professional development programmes which make teachers interested in the development of their professional knowledge were those which had content knowledge being taught in the teacher networks. According to Borko (2004), teacher development programmes can be seen as a space from which teachers:

> *"enhance their knowledge and develop new instructional practices"* (Borko, 2004, p. 3).

Borko (2004) also argues that three important aspects which define professional development (PD) must firstly include teachers (learners of the programme). Secondly, the intervention (the programme itself) and thirdly the context from the PD. Another aspect which is deemed important in teacher development programmes is continuity. Research in education has shown that longer study times within development programmes, collective professional development rather than personal and reform-based activities all set an optimal environment for effective teacher development (Supovitz & Turner, 2000). Thus, researchers and teacher educators are also cautioned against short term or once-off injection teacher development programmes. Such once-off programmes have proven to be ineffective in improving teacher practices (Broad & Evans, 2006).

Guskey (2002) argues that TPDP is an important aspect of teaching practice and is good for school and learner improvement. Evidence of successes in improving the quality of teacher professional knowledge is seen in several studies (Anney & Hume, 2014; Pitjeng-Mosabala & Rollnick, 2018; Zhang et al., 2015). Anney and Hume (2014) conducted a study which focused on under-qualified science teachers and how to enhance untrained science teachers' PCK in developing countries through teacher learning communities. Pitjeng-Mosabala & Rollnick (2018) introduced novice unqualified graduate teachers to the knowledge needed for science topics. The study by Zhang et al. (2015) focused on understanding the needs of in-service teachers for professional development including science teachers who are teaching science with no background qualification to teach the subject.

In a study by Zhang et al. (2015) focus was on aspects of PD which make it effective from their design. Thus, PCK framework was used to investigate teachers' needs for a PD. The PD was based on selected specific science topics. The study targeted teachers' perceptions of where they needed improvement. Amongst the topics that appeared to be challenging to the majority of these teachers was the topic on matter. Their reasons varied with about 23% of 230 teachers stating that they needed improvement in certain topics because they either lacked content knowledge in the topic or training while some had little interest in the topic itself. Finally, the study showed that such teachers needed improvement on different traits of PCK and involved instructional strategies, knowledge of learners, curriculum and knowledge of assessment.

The study by Zhang et al. (2015) seems generic. For example, teachers chose several science topics from life sciences to physics and earth sciences. However, such research could be furthered by approaching content knowledge topic by topic. Research in PCK (Aydin, Friedrichsen, Boz, & Hanuscin, 2014; Mavhunga, 2016) argue that for development purposes the level at which teacher content needs to be approached is at Topic-Specific level rather than the multi-discipline approach by Zhang et al. (2015).

Anney and Hume (2014) looked at strategies for improving the PCK of untrained science teachers in Tanzania. In a study by Loughran, Mulhall & Berry (2004) teachers were exposed to different modules including general PCK using Content Representations (CoRes).The authors reported improvement in the quality of teachers' PCK as it was seen in their classroom practice. A study by Pitjeng-Mosabala and Rollnick (2018) was concerned by little exposure to teaching experience in uncertified science teachers and thus little understanding of the transformation of content knowledge. An intervention based on exposing such teachers to the knowledge needed to transform their content knowledge was conducted. Teachers were explicitly exposed to the TSPCK components and the effectiveness of such intervention was measured through TSPCK instrument and CoREs (Content Representations). Furthermore, the general information about teaching, science content-related topics including a session on re-visitation of the particulate nature of matter were part of what was done in this intervention. The findings from this study suggest that introducing teachers with little teaching experience to the TSPCK components improved their PCK in the particulate nature of matter.

Both studies by Pitjeng-Mosabala and Rollnick (2018) and Anney and Hume (2014) point to a measure of success when the PCK and TSPCK framework is used in a professional development programme. Thus, there is a reasonable chance, while it remains unknown, that the PCK related framework proposed in this study may be useful. While PCK at the Topic-Specific level was used in the content of TPDP designed for this study, there are features of professional development programmes reported to be essential for success. Supovitz and Turner (2000) defined effective professional development programmes as having features such as sustainability, target on content knowledge development, inquiry forms of teaching, practice-orientated and participatory rather than lecture-based exposures. Similarly, Main and Pendergast (2015) argue that the core features of continuous professional development should include:

(i) *target content knowledge development* – the degree of focus on improving teachers' content knowledge (Topic-Specific PCK in the particulate nature of matter)

(ii) *active learning* – the extent to which the TPDP offers teachers to become engaged in the meaningful analysis of teaching and learning

(iii) *collective participatory orientated* – the degree of emphasis on groups of teachers from school learning together or individual teachers from many schools

(iv) *coherence* - the degree to which TPDP fits with broader educational agendas to reform teaching, links to previous TPDP and encourages continuing professional communication among teachers

(v) *duration* – the number of hours of TPDP

The above mentioned are structural features of an effective TPDP as proposed by Garet, Porter, Desimone, Birman, and Yoon (2001). It maps the core and structural features of an effective PDP similar to those proposed by Main and Pendergast (2015). These were the five features that were focused on as they were adopted and recognized as important for inclusion in the structure and approaches used in the teacher professional development intervention designed for this study. According to Guskey (2002), one of the features of an effective teacher professional development programme includes its ability to be sustained and sustainable. The author argues that teachers are normally reluctant to implement new procedures and teaching practices hence an effective teacher professional development will use different techniques to ensure sustainability. (Hooker, 2008). The core features as defined by Main and Pendergast (2015) above are the guidelines to a technique adopted in this study to ensure sustainability.

Due to the predicaments of out-of-field science teachers in rural areas such as weak content knowledge, content knowledge becomes a critical feature which will be of focus in this study. Teacher professional development programmes must not simply be training but encourage inquiry forms of teaching with modelling that provides teachers with scientific reasoning beyond textbook memorization. Thus, in this study, the model of transforming content knowledge for planning and enactment in class was used to design the proposed professional development. According to Hooker (2008), practice-orientated professional devetlopment programmes stand high chances of becoming a success as opposed to the unilateral approach which focuses more on theory and never allow teachers an opportunity to gain knowledge for practicing the newly learnt techniques. A follow-up and continued support beyond workshops are crucial aspects of an effective professional development programme. All features mentioned above were acknowledged and found to be relevant to this study. These features were thus considered in the research design of the proposed intervention, see chapter 4.

2.4 Difficulties about learning the particulate nature of matter

The focus of the study was on Natural Sciences (grades 8 and 9), particularly the chemistry section. The topic of interest was the particulate nature of matter which is introduced largely at Grade 8 according to Curriculum Assessment Policy Statement (CAPS) (DBE, 2011). According to the CAPS document (DBE, 2011) Junior Secondary teachers at Grade 8 level were expected to teach the topic of the particulate nature of matter for 7 weeks and then teach the topic on chemical reactions for one week. This meant that over 80 % of Grade 8 chemistry was based on the topic of the particulate nature of matter. Andersson (1990) argued that the particulate nature of matter is regarded as challenging due to its abstract character. Nonetheless, the particulate nature of matter forms a basis for chemistry understanding, and is thus considered as a fundamental concept in chemistry (Gabel et al., 1987). Generally, chemistry topics including the particulate nature of matter operate at three levels which are macroscopic, sub-microscopic and symbolic level. According to Loughran, Mulhall, and Berry (2004), the core ideas which are central to the topic are:

1) Matter is made up of small bits which are called particles

2) There are empty spaces between particles,

3) Particles are always in constant motion,

4) Particles of different substances are different

5) There are different types of small bits of substances,

6) Atoms cannot be created nor destroyed but their arrangement may be changed.

As discussed above, the particulate nature of matter is about connecting visible things (macroscopic) which surround our daily lives and connect that which we see with what happens at the level of matter which we cannot see (sub-microscopic). This connection seems to the source of all misconceptions that learners have about the topic. In a study conducted by Andersson (1990), it is suggested that the language used by both text-books and teachers fail to make a clear distinction between particles (i.e. atoms or molecules) and substances. There are many misconceptions arising from learner-thinking concerning this topic. For example, learners tend to think that if a substance disappears from the macroscopic level, it disappears at the microscopic level too. This means they think atoms or molecules disappear instead of being rearranged (Wightman, Green & Scott 1986).

However, understanding of concepts in the particulate nature of matter does not only end at the Junior Secondary level. Grade 10 chemistry further develops this construct and applies it to teach topics such as kinetic molecular theory. At grade 11, these concepts are developed further into stoichiometry. OFTs in this study were not subject-specialist in chemistry. However, teaching this topic at Junior Secondary level requires a deeper insight into the topic, which means, it requires that a teacher does not only look at prescribed chemistry concepts at grade 8. It also requires an understanding of the usefulness of the topic in the grades above and to understand how a particular topic relates to the overall chemistry domain needed at the school level.

The TSPCK is the teacher knowledge that provides a guideline to how teachers reason their content knowledge in a specific topic with respect to their learners. This includes teachers' consideration of the entire curriculum awareness and how the topic links and prevails itself in other topics. PCK at Topic-Specific level portrays knowledge that teachers need to know how to formulate coherent conceptual narratives using their knowledge of the curriculum, to understand the curriculum demands imposed on learners in a specific topic and how to support students when they do not understand.

This knowledge helps teachers to know what concepts to bring to formulate a coherent conceptual narrative and when and what to leave out and thus sparking interest in the learner to engage while constructing their understanding of concepts. Such knowledge might be useful to out-of-field teachers as it exposes them to the reasoning behind a particular topic and develops the professional knowledge needed to teach a specific topic. Thus, in this study exposure to a signature intervention is implemented to improve the quality of TSPCK, eTSPCK and content knowledge of out-of-field teachers.

2.5 Pedagogical Content Knowledge

Shulman (1986) defines PCK as an amalgamation of content and pedagogy into forms which are useful for teaching and can be understood by learners. Central to PCK is the transformation of content knowledge from teachers' understanding into various forms that support students' learning to comprehend the topic. By definition, PCK requires that teachers should possess content knowledge in the subjects they teach (Shulman 1986). In the paper by Shulman 1987, the idea of PCK is further explained as teachers' special form of professional understanding (Shulman, 1987), providing a platform for CK blended with pedagogy as a prerequisite for the journey of teacher preparation. PCK was first described as knowledge which considers how teachers transform their knowledge in a particular topic to ways in which they teach content, having identified what they know about the subject, students and the curriculum they are dealing with. Shulman (1987, p. 8), presented seven categories on which teacher knowledge for teaching should be premised. These include:

(i) Content knowledge (CK)
(ii) General pedagogical knowledge,
(iii) Curriculum knowledge,
(iv) Pedagogical content knowledge (PCK),
(v) Knowledge of learners and their characteristics,
(vi) Knowledge of educational contexts,
(vii) Knowledge of educational ends, purposes and values, and their philosophical and historical backgrounds.

While PCK is defined as an amalgamation of content and pedagogy, in the seven knowledge categories above, these are presented as different knowledge bases for teaching meaning that CK has a significant role or impact on PCK as it forms part of the knowledge categories that define PCK. (Shulman, 1987, p. 5).

Cochran, DeRuiter and King (1993) were among early researchers after Shulman (1986) who found the theoretical notion of PCK interesting and expanded it to define the concept from their point of view. The authors developed a model of Pedagogical Content Knowing (PCKg) which they explained as a dynamic process that continues to develop throughout a teacher's career. In particular, the model proposed offered pedagogy, subject matter, students and context as knowledge categories which are the sources for the development and growth of PCK. The model describes these knowledge domains as rather dynamic and continued to grow, thus, producing growth in the level of PCK of teachers. Cochran et al. (1993) acknowledged Content Knowledge as one of the knowledge categories which contributes to the development and growth of PCK. As a result, there is substantive literature of studies which seek to elaborate on the correlation between CK and PCK. In a study by Rollnick et al. (2008), these authors developed a model to capture and portray PCK. The authors inferred that the internal teachers' knowledge domains initially proposed by Cochran et al. (1993) manifested through classroom observations called manifestations. Davidowitz and Rollnick (2011) revised this model and found that teachers' beliefs also interacted with teachers' internal knowledge domains as described by Cochran et al. (1993) in the transformation of Content Knowledge from teachers' understanding into various forms that could help students comprehend the topic.

2.5.1 Pedagogical reasoning

Science Education research has widely acknowledged PCK as the knowledge that encompasses teachers' reason about their content knowledge, and it enables them to be flexible in using their CK, adjusting it according to the conceptions and misconceptions of their learners. This reasoning process gives insights into the knowledge of teachers' conceptual representations and instructional strategies \in support of students' learning.
Shulman 1987 presented a theoretical framework of pedagogical reasoning and action process. The framework consisted of six aspects of reasoning namely (1) Comprehension, (2) Transformation, (3) Instruction, (4) Evaluation, (5) Reflection and finally (6) New Comprehension. Shulman (1987) argued that before teachers could enact their lessons in a classroom setup, there was some form of thinking and reasoning that influenced their action (comprehension stage). The stage of thinking and reasoning about the subject matter is where teachers make sound thinking about the transformation of content knowledge in a specific topic into a teaching form that students can understand.

Shulman also added that the thinking and reasoning behind teacher actions were visible in the transformation stage before real classroom instruction. The transformation stage is informed by four processes namely (i) preparation, (ii) representation, (iii) selection and (iv) adaptation and tailoring. These four processes of the transformation result in a plan or a set of strategies to present a lesson or course. The pedagogical reasoning and action framework provide an opportunity to analyse the teaching process unique to the transformation of content knowledge into chunks of instruction that student can easily understand. As alluded to in the section above, there are models of PCK proposing knowledge domains that inform PCK as the transformation of content knowledge. The pedagogical reasoning framework provides a pathway to how teachers reason and transform content knowledge through the knowledge components which bring about the transformation of specific content knowledge, the actual classroom action and reflection about the delivered lesson. Pedagogical reasoning maps the reasoning trajectory from personal comprehension of ideas by the teacher to the transformation of content ideas for comprehension by students. Thus, measuring the impact of exposing out-of-field teachers to learn (i) content knowledge in the particulate nature of matter (ii) components of TSPCK for transforming personal comprehended content ideas by teachers for students to comprehend and (iii) TSPCK in action, offers useful information about teachers' pedagogical reasoning ability.

2.5.2 Subject Matter Knowledge

In the original conception of PCK by Shulman (1986) one of the knowledge domains that appeared strongly as a matter of concern was 'the missing' subject matter knowledge (SMK) in teacher education. The teacher qualification examinations were rather focused on testing teachers' ability to teach rather than testing SMK. In teacher education, the term subject matter knowledge and content knowledge are sometimes used interchangeably. In the paper by Shulman (1986) the term subject matter content knowledge appeared as one of the three kinds of Content Knowledge alongside with Pedagogical Content Knowledge.

However, in a later published work by Shulman (1987) which gave a comprehensive account of knowledge and teaching, Content Knowledge rather than Subject Matter Content Knowledge was one of the seven teacher knowledge base categories. In this paper, pedagogical content knowledge and curriculum knowledge were distinct knowledge domains of the teacher knowledge base. Cochran et al. (1993) defined SMK as the knowledge encompassing content knowledge. Balls, Thames and Phelps (2008) rather looked at content knowledge as an overarching category that included SMK. The deferring terminologies of SMK are informed by that fact that there are two perspectives on the nature of SMK which is (i) Didactic school of thought and (ii) PCK perspective.

Schwab (1978) defined SMK in terms of its structure proposing that that part of the SMK structure was substantive knowledge and some part was syntactic knowledge. Substantive Knowledge referred to the body of facts in a particular discipline while Syntactic Knowledge included ways in which the discipline evaluated and accepted new knowledge. According to Schwab (1978), the fundamental principle informing the structure of SMK for teaching is that it should follow a highly flexible pattern that is continually adapted and modified to fit particular problems and situations to which it is applied. In science education particularly, the didactic school of thoughts implies that for teachers to conceptualise SMK they needed to adapt and modify content from discipline considerations to content elected to be taught and characteristics of students for it to produce teaching content. In particular, the didactic system promotes an understanding that the knowledge to be taught and the knowledge taught undergoes complex transformation processes at various stages of selection and teaching, separating teaching knowledge from subject matter knowledge per se.

This understanding in Schwab's proposition overlaps with pedagogical reasoning and action framework proposed by Shulman (1987) arguing that the act of teaching originated from a comprehension of subject matter followed by a vigorous process of transformation. The transformation process comprised of four stages (i) preparation, (ii) representation, (iii) selection and (iv) adaptation and tailoring. The transformation process was a stage before actual teaching in the classroom. This discussion leads to the second perspective which is from PCK school of thoughts. Firstly, the PCK perspective makes a distinction between SMK and PCK. The transformation of content is the key principle that distinguishes SMK for teaching and the original content knowledge from academic knowledge. The SMK from PCK perspective helps us understand how teachers elucidate subject matter in new ways, reorganize it and partition it, clothe it in activities and emotions, in metaphors and exercises and examples and demonstrations for students' understanding. From the discussions above, it is evident that SMK is the heart of teachers' practice and therefore in preparing teachers. It is the first step to ensure that they know the material they have to teach. Therefore, learning of SMK in teacher education becomes a minimum pre-requisite for teaching it. In this study, a similar perspective of Shulman (1987) which rather uses the term content knowledge instead of subject matter content knowledge was adopted.

2.6 Topic Specific nature and models of PCK

The Topic-Specific nature of PCK is described in a wide range of literature, (Geddis & Wood, 1997; Magnusson, Krajcik & Borko, 1999; Mavhunga & Rollnick, 2013; Veal & MaKinster, 1999). These scholars have proposed different models of PCK which had foci on accessing PCK of expert teachers and how PCK developed for novice teachers. Each of these models described knowledge components of PCK which brought about the way that it develops. One of the notable contributions made by PCK researchers describes PCK as being Topic-Specific (Mavhunga & Rollnick, 2013; Magnusson et al., 1999; Veal & MaKinster, 1999). Magnusson et al. (1999) defined PCK as the knowledge base of teachers in a specific topic which guides learners to effective learning. The model of Magnusson et al. (1999) demonstrates PCK as teachers' knowledge of helping learners to comprehend content knowledge in a specific topic. The Magnusson et al. (1999) model describes the interconnectedness between the domains of teacher knowledge and their link to PCK, see Figure 2.1.

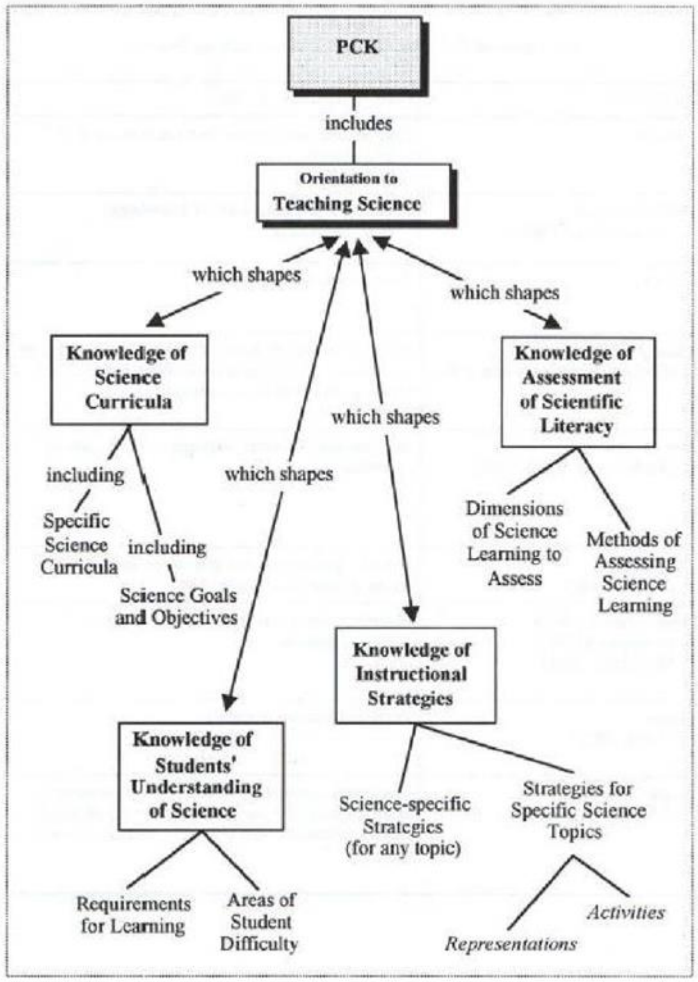


Figure 2.1: PCK model for science teaching (Magnusson et al. 1999, p.99)

The model describes PCK as consisting of several components while showing the link of these components to science teaching. The model rather illustrates components of PCK as subject-specific rather than general. The knowledge domains from which PCK emerges include knowledge of students' understanding of science, knowledge of the science curriculum, knowledge of the assessment of scientific literacy and knowledge of instructional strategies. These knowledge domains are informed by orientations to teaching science and in turn, depend on the above-mentioned knowledge domains. Of particular interest to this study is the proposition of instructional strategies as one of the knowledge domains showing how their model and specifically the Topic-Specific nature of PCK are aligned with knowledge of instructional strategies. The model implies that the knowledge of instructional strategies in a specific topic is seen through conceptual representations and activities as teachers articulate in a classroom environment. The Mavhunga and Rollnick (2013) model of Topic-Specific PCK is based on the above mentioned PCK conceptualisations and model and will be the theoretical construct for this study. The details of the Mavhunga and Rollnick (2013) model are discussed in section 2.8. One of the key aspects of the Mavhunga and Rollnick model are the five knowledge components of TSPCK from which transformation of content knowledge emerges. The Mavhunga and Rollnick model was based on the study by Geddis and Wood (1997). Geddis and Wood (1997) focused particularly on the relationship between Content Knowledge and PCK, thus further elaborating on knowledge possession, which informs the transformation of CK. For example, in their focus on teaching as a process of transformation of Content Knowledge, Geddis and Wood (1997) observed that this process emerged from knowledge of learners' prior concepts, subject matter representations, instructional strategies, curriculum materials and curricular saliency.

Veal and MaKinster (1999) developed two taxonomies of PCK, namely general PCK and attributes of PCK. In the taxonomy on attributes of PCK, the authors provide a hierarchy in the relationship between the components arguing that the components recurring most frequently for the PCK taxonomies provide clues about components to be considered the most important. The hierarchy of General PCK taxonomy is shown in Figure 2.2 which demonstrates that the initial level in the hierarchy is General PCK.

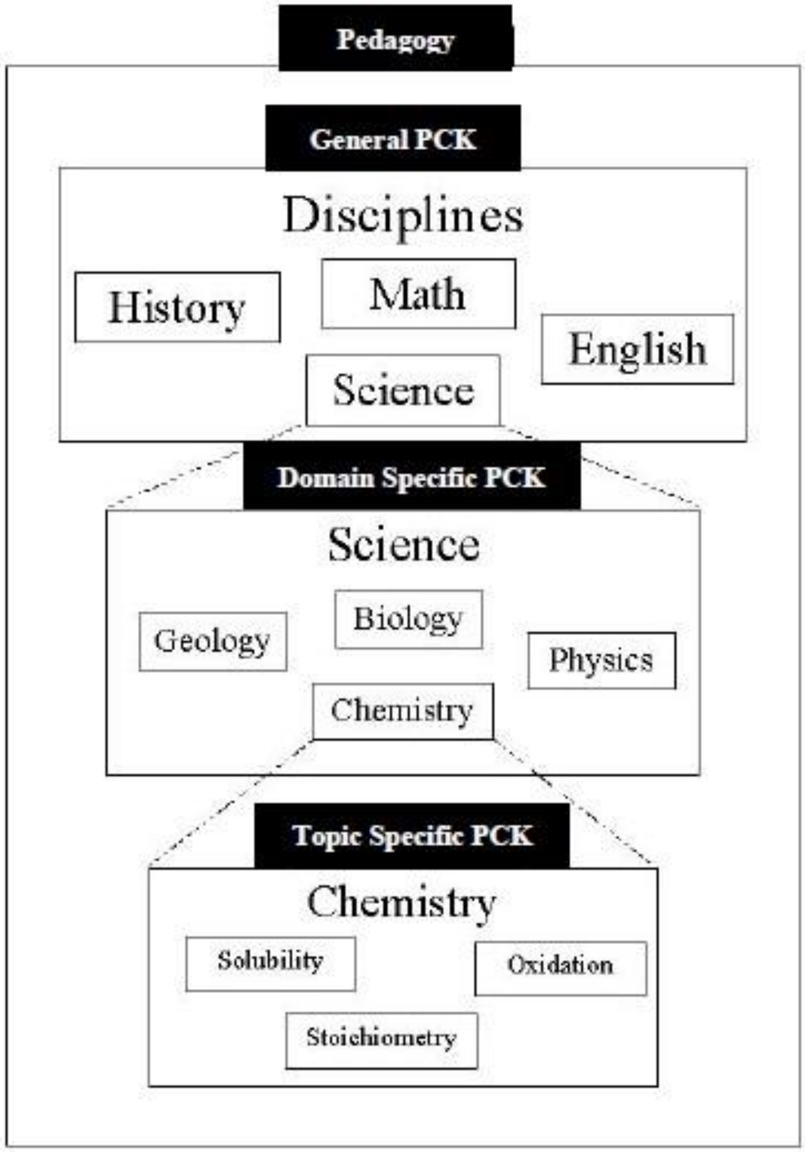


Figure 2.2: A model of general taxonomy of PCK (Veal & MaKinster 1999, p.7)

The model above explains the hierarchy of PCK components from General PCK which is the knowledge of pedagogical skills across all disciplines to the most specific level in the PCK components, which is Topic Specific PCK. This study focused specifically on the lower part of the general taxonomy which is Topic Specific PCK. Mavhunga and Rollnick (2013) also considers the transformation of content knowledge to be topic-specific, which relates to the level of Topic-Specific PCK in the taxonomy in Figure 2.2. Key to this level is the argument that within a particular domain such as science there are different topics.

Each of these topics needs specific subject representations with specific instructional strategies which might be different from a case of another topic within the same domain. It is thus reasonable that one takes into consideration how teachers address the transformation of content knowledge at Topic-Specific level.

2.7 Consensus Models of PCK

While the contributions from various models since the conception of PCK have played a pivotal role in elaborating various aspects of PCK, it also became clear that PCK research lacked consensus about the nature of PCK and its link to student outcomes. The outcome of this concern was a call for the first international PCK summit which led to an agreement on the definition of PCK and a consensus model. The Model of teacher Professional Knowledge and Skill, (TPK & S) including PCK illustrates knowledge interactions from the most general level (Teacher Professional Knowledge Bases) to Topic-Specific, followed by classroom practice and link to student outcomes.

2.7.1 Teacher professional knowledge and skill model

The study by Gess-Newsome (2015) on PCK led to consensus model which was called Teacher Professional Knowledge and Skill (TPK & S). The model depicts different layers of teacher profession as shown in Figure 2.3.

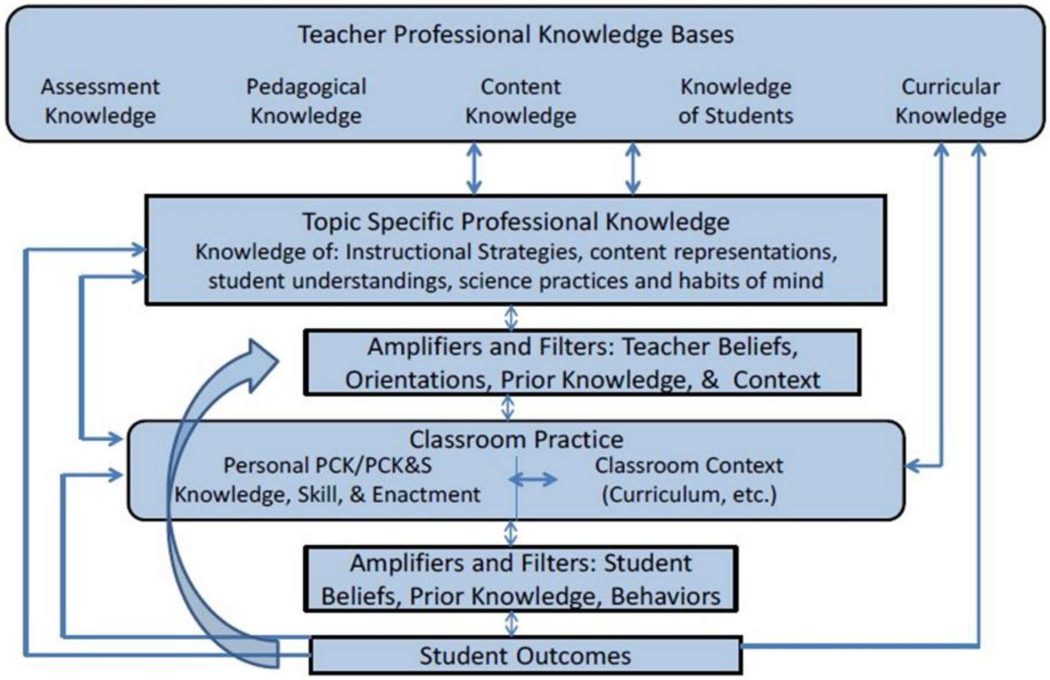


Figure 2.3: The Consensus Model of Teacher Professional Knowledge & Skill (Gess-Newsome, 2015, p. 36)

The consensus model shows that in the teaching profession, teachers have a Teacher Professional Knowledge Base (TPKB) which applies not only to science teachers but also to teachers across disciplines. This knowledge base is defined by five general knowledge domains of teacher professional knowledge, which include 1) assessment knowledge, 2) pedagogical knowledge 3) content knowledge 4) knowledge of students and 5) curricular knowledge (see Figure 2.3). Teachers usually acquire this knowledge base through formal education programmes.

This teacher knowledge base underpins the second layer of knowledge called Topic Specific Professional Knowledge (TSPK). This knowledge base is the kind of knowledge which is shared among professional teachers who are teaching the same topic and from best research and practices in the field. This knowledge is also referred to as canonical PCK. In this level, teachers draw knowledge for planning and preparing their lessons. At this level content knowledge is unpacked and dealt with at a topic level. This knowledge is defined by the following knowledge components 1) instructional strategies, content representations, student understandings, science practices and habits of mind and is not bound by any context. Following after the TSPK is an enactment of this knowledge in a classroom practice which is filtered or amplified through influences such as teacher beliefs, orientations and context of teaching. The model shows that when teachers have the professional knowledge needed to teach specific knowledge, such knowledge remains less effective if not enacted in classroom practice. The classroom space grants a teacher an opportunity to enact his/her planning and thinking of the lesson. It is at this level that the teacher draws from his/her Topic-Specific professional knowledge to decide on representations and instructional strategies which suit the context of their classroom. At this point, the observed enactment through classroom practice is called personal PCK, and is only bound within classroom practice, and is an amalgam of knowledge for reasoning and planning to teach with the act of teaching a specific topic.

However, as researchers of science education in PCK applied the model in their various research fields across the globe, it became clear that the model needed to be revised. Moreover, the 2015 Consensus Model rather focused more on inserting PCK within the Teacher Professional Knowledge which resulted in an ambiguous description and application of the model.

2.7.2 The refined consensus model of Pedagogical Content Knowledge

On the Revised Consensus Model (RCM), the process which the revision of the 2015 Consensus Model (CM) was shaped by knowledge and experiences of the work done on PCK research across the globe and among those in the research work contributed by South African context of PCK at Topic-Specific level. The construct of Topic-Specific Pedagogical Content Knowledge which has framed this study by Mavhunga and Rollnick (2013) is one of the research domains that contributed to the RCM.

The revision of the model was therefore necessitated by limited detail about PCK on the 2015 CM which had its focus on elaborating personal PCK and Skills in the definition of PCK. The second summit of PCK sought to address these specifics to provide science education research with clearer descriptions of specialised professional knowledge which multi-educators in the field possess.

Figure 2.4 gives the recent Revised Consensus Model of PCK in science education:

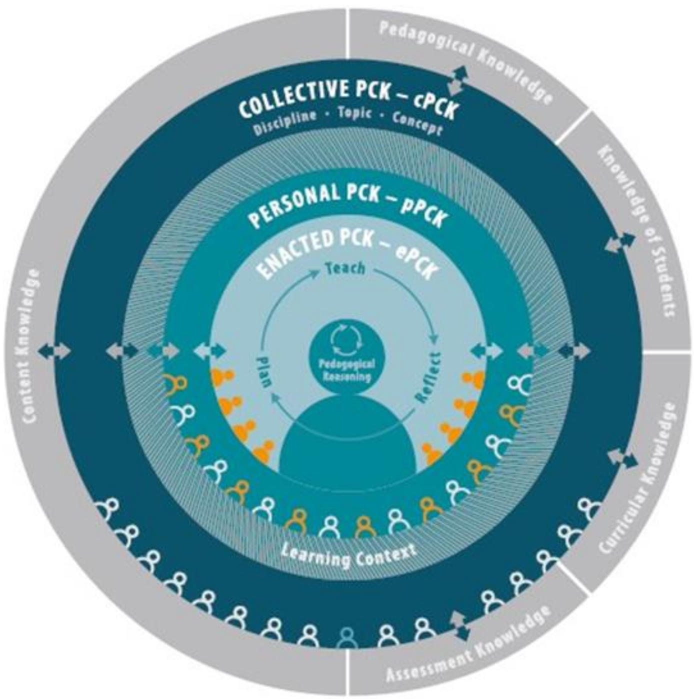


Figure 2.3: Refined Consensus Model of Pedagogical Content knowledge (Carlson & Daehler, 2019, p. 83)

In Figure 2.4, the RCM identifies more explicitly three realms of PCK as collective PCK (cPCK), personal PCK (pPCK) seen through planned PCK and enacted PCK (ePCK). This model represents these three realms both in a clearer diagram form and explanatory text. Collective Pedagogical Content Knowledge (cPCK) is the knowledge where science teachers could draw on and develop their teacher professional knowledge about PCK through coursework and publications shared as common teacher knowledge. When teachers have access to cPCK they can then utilise that understanding and apply it in their teaching context as personal Pedagogical Content Knowledge (pPCK), not withholding the fact that, there are filters and/or amplifiers, which make this permissible.

The personal PCK (pPCK) therefore prevails when teachers personalize such shared knowledge in their understanding for use in planning to teach context and manifest in teachers' practice in class as enacted PCK (ePCK) (Carlson & Daehler, 2019).

Thus, RCM positions PCK studies by specifying the realm in which the study is situated and indicates the grain size at which the investigation is located. As the RCM acknowledges the 2015 CM, it asserts that the RCM does not seek to override the 2015 CM but rather an elaboration on the specificity of PCK grain sizes namely discipline-specific, Topic-Specific and concept specific PCK. The RCM model, therefore, projects the professional journey of a science teacher as that which consists of three distinct realms of PCK. This study is located within the grain size of PCK referred to as Topic-Specific which the RCM identifies as accessible in each of the three PCK realms. The implementation of the intervention with an explicit focus on TSPCK is premised within the collective PCK of the RCM at Topic-Specific level. The impact of the implemented intervention is sought to improve the quality of OFTs' TSPCK, a stage which was premised within the pPCK of the RCM at a Topic-Specific level. Additionally, the study investigated the quality of eTSPCK of the OFTs in the particulate nature of matter before and after the intervention, this stage was premised with ePCK realm at Topic-Specific level.

2.8 Topic Specific PCK

PCK research has recently advanced to a level concerning knowledge for teaching science topics one by one called Topic Specific Pedagogical Content Knowledge (Mavhunga & Rollnick, 2013). There are models which focus on content knowledge and teaching approaches and some use PCK. However, the scholarly work from PCK research came to a consensus that PCK, as it stands, is too generic and implicit (Gess-Newsome, 2015). Research on PCK has identified both personal and enacted PCK as having a significant role in teacher education. It is argued that that how teachers plan for their lessons in classrooms, including the kind of knowledge they have about content knowledge and teaching strategies needed for their learners to understand should be linked to the implementations of PCK in a classroom, (Aydeniz & Kirbulut, 2014). The same reasoning applies to the construct of TSPCK in that the knowledge a teacher has in teaching a specific topic is equally valuable as how a teacher implements that knowledge in a classroom. The consensus model has established a clear link between knowledge a teacher has in a specific topic and enactment of that knowledge in classroom practice (Gess-Newsome, 2015).

According to Mavhunga and Rollnick (2013), the construct of TSPCK is defined as a transformation of content knowledge through the five components of TSPCK which include, 1) learners' prior knowledge, 2) curricular saliency, 3) what is difficult to learn, 4) representations and 5) teaching strategies. Central to the construct of TSPCK is not only understanding of these knowledge components but the development of a skill to use them interactively. It is argued that when teachers are exposed to deliberate and explicit discussions about pedagogical competence needed to transform CK in a specific topic, it further develops teachers' ways of reasoning their CK with respect to their learners' understanding, and this is a general goal of PCK (Mavhunga & Rollnick, 2013).

There is strong evidence that signature intervention which explicitly teaches TSPCK and its components develops teaching expertise of pre-service teachers. In a study conducted by Luft, Hill, Nixon, Campbell, and Dubois (2015), content knowledge forms a base for the transformation of content and argue therefore that it is important to conceptualize this knowledge needed for the transformation of content knowledge for teaching. Topic-Specific PCK is one of those constructs which adds to the knowledge needed for teaching. The diagram in Figure 2.5 shows the model of TSPCK by Mavhunga and Rollnick (2013).

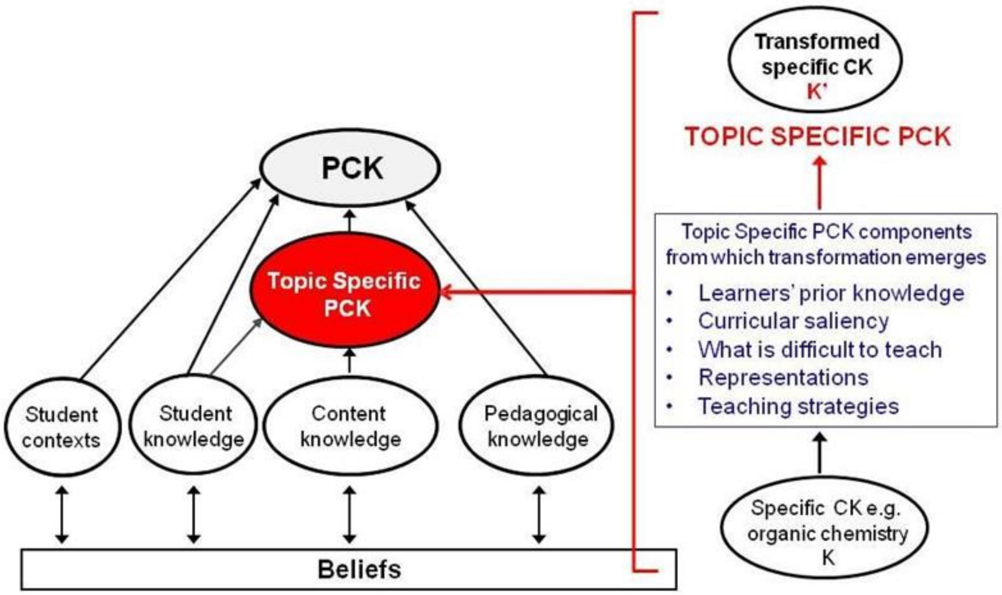


Figure 2.5: Model of Topic-Specific PCK (Mavhunga & Rollnick 2013, p. 115)

Several studies suggesting the Topic-Specific nature of PCK have been published in science education research locally (Pitjeng-Mosabala & Rollnick, 2018) and internationally (Luft, Hill, Nixon, Campbell, & Dubois, 2015). There are studies suggesting the manner in which PCK at the Topic-Specific level develops (Mavhunga & Rollnick, 2013; Nilsson & Loughran, 2012; Pitjeng-Mosabala & Rollnick, 2018). In these three studies, the focus is on the transformation of content knowledge into a pedagogically powerful form. They problematize the knowledge component alone which teachers should possess in a specific topic. In these studies, the influence of PCK in chemical equilibrium for pre-service teachers was investigated by Mavhunga and Rollnick (2013). Nilsson and Loughran (2012) investigated how PCK develops in pre-service teachers teaching the topic of air, while Pitjeng-Mosabala and Rollnick (2018) discussed the effect of TSPCK-based intervention for novice teachers teaching the particulate nature of matter. Each of the studies above elaborates on the influence of TSPCK on teachers' pedagogy.

In a study by Nilsson and Loughran (2004), pre-service teachers were exposed to PCK through the topic of air as a construct which they could use to plan and assess their professional knowledge as beginning teachers through Content Representations

(CoRes). CoRes are primarily tools used to articulate and portray the PCK of science teachers. CoRes were originally developed by small groups of experienced science teachers working in teams, leading to the identification of 'Big Ideas' for teaching a specific topic (Loughran et al., 2004). The process from which they developed their PCK was based on the questionnaires or interviews that were interrogating their reasoning behind learning science teaching, how confident they were to teach the subject and what they perceived as meaningful to their learning to teach science.

In a study by Mavhunga and Rollnick (2013) TSPCK components were introduced in an intervention programme for 16 science pre-service teachers. Each of the five components of TSPCK was discussed, one component at a time. Articles as pre-session readings were used to elaborate further on each of these components. Each component of TSPCK was explained through the core universal concepts of chemical equilibrium, emphasizing teaching situations of content and not content *per se*. The findings from the study suggest that such intervention exposed pre-service teachers to the knowledge needed for teaching before they could start practising as teachers. This established relationship between the PCK and transformation of content knowledge even though the latter is understood to be as a result of the PCK.

In some of the studies discussed above, there is in-depth exposure to content knowledge while exposing pre-service teachers to TSPCK. The most dominant findings in each of these studies are the understanding that exposing teachers to this construct improves not only their skills of integrating content knowledge and pedagogy in a specific topic (TSPCK) but also their content knowledge improved. In terms of school experience, classroom management, school policies and so forth, out-of-field teachers might have developed that experience through years of teaching compared to pre-service teachers however both groups lack the PCK. The limitation of the TSPCK in pre-service teachers is due to a lack of pedagogical skills. The TSPCK in the OFTs becomes limited due to a lack of content knowledge as opposed to pedagogical knowledge. However, the studies above on the TSPCK indicated that it is not only pedagogical skills which can be improved by the TSPCK but also content knowledge too. In this study, the construct of the TSPCK as a possible vehicle to advance the professional development intervention programme for teachers who are teaching chemistry out of their field of expertise is adopted. The study investigates the development of this construct in out-of-field teachers, specifically the development of their content knowledge, the TSPCK and the eTSPCK before and after exposure to intervention with an explicit focus of TSPCK.

- **The simplified illustration of RCM**

The development of RCM requires the PCK studies to be clear about the level at which their studies are located. Mavhunga (2019) illustrated the position of the TSPCK through a simplified model of demonstrating the multidimensional nature of the PCK in the RCM. In Figure 2.6 is the simplified RCM version by Mavhunga (2019) that makes explicit the continuum of PCK grain sizes within each of the three realms of PCK.

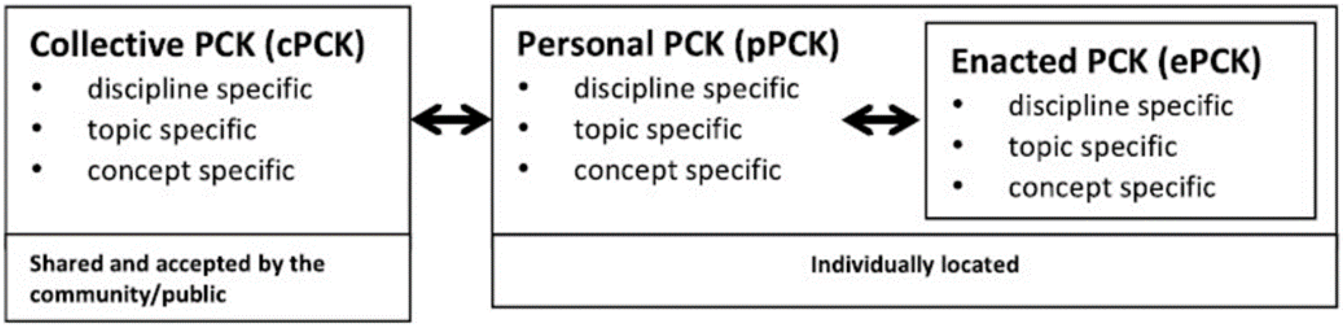


Figure 2.4: A simplified illustration of the RCM for PCK grain sizes within the three realms of PCK (Mavhunga, 2019, p. 131).

Mavhunga (2019) argues that the developmental pathway of teacher professional knowledge could be understood as that which consists of the three distinct but interrelated realms of PCK, namely, the collective PCK, personal PCK and enacted PCK. The author argues that the development through these three realms could be experienced at discipline-specific, Topic-Specific and concept specific level. Additionally, the collective PCK was defined as knowledge shared and accepted by the community of science education experts including best research and professional practices that mean PCK at this realm was context-free. The personal PCK and enacted PCK were individually located meaning teachers adapted and modified the context-free knowledge from cPCK into their contexts suitable to their students. The adoption of PCK in this study was mainly for investigating the development of teacher professional knowledge of OFTs and this developmental pathway could be simplified to that which consists of the three interrelated realms of PCK (Mavhunga, 2019). Due to the explicitness and clarity on the simplified model of RCM, this study will adopt it as one of the framing models. The model provides insight into concepts about the development path of teacher PCK in the in-service professional learning environments among others.

2.9 The conceptual framework of this study

The study acknowledges the broader conceptualisation of PCK (Shulman, 1986) which defines teaching as taking place when teachers transform their CK into a teachable form.

The framework in this study specifically focuses on the Topic-Specific level of the PCK taxonomies (Veal & MaKinster, 1999). The conceptual framework for this study was drawn from the conceptualisation of Mavhunga (2019) and the Mavhunga and Rollnick (2013) model and in Figure 2.7 is the proposed conceptual framework that was modified to suit this study.

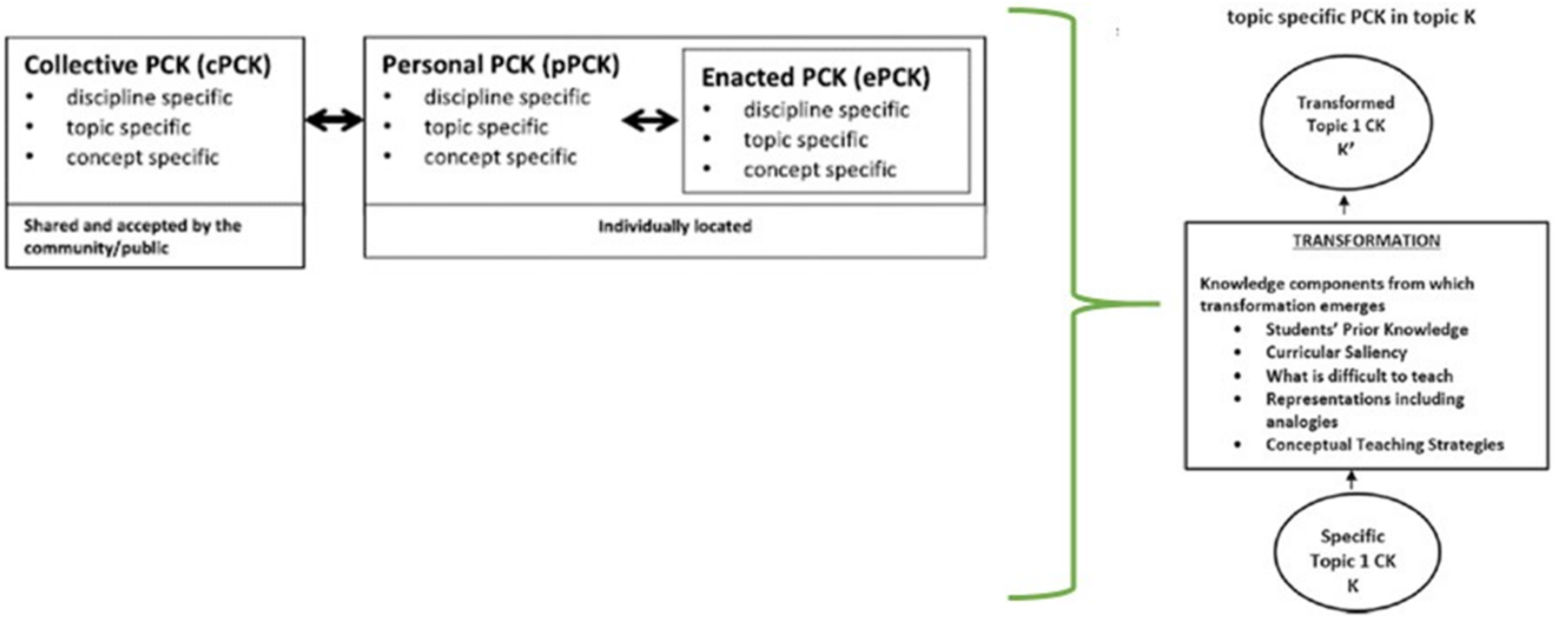


Figure 2.5: Conceptual framework for the development of TSPCK for OFTs

The key aspects of the Mavhunga and Rollnick (2013) model of TSPCK are the five components underpinning the transformation of CK into a teachable form. Literature (Ball, Thames, & Phelps, 2008) suggests that content knowledge alone is not enough and should be amalgamated with the knowledge for teaching and therefore the TSPCK framework with its five components has been chosen. This understanding is similar to that of Geddis and Wood's (1997) concept of pedagogical interactions through PCK components in a specific topic.

The simplified model of RCM by Mavhunga (2019) illustrates more explicitly the three developmental realms of PCK (cPCK, pPCK and ePCK) asserting that the development is experienced through the three-grain sizes of PCK (discipline, topic and concept – specific). The five components of transformation in Mavhunga and Rollnick (2013) underpin the development experienced across the three realms of PCK of the Topic-Specific grain size. The development of out-of-field teacher's knowledge was investigated within the Topic-Specific grain size of the three PCK realms. Firstly, the signature intervention carried out in this study exposed OFTs to TSPCK through the five knowledge components of the TSPCK model. The TSPCK learnt by OFTs at this point of the study is located within cPCK at Topic-Specific level on the simplified RCM model. Mavhunga (2019) further proposed in her illustration of RCM that cPCK was acquired through shared knowledge among professionals, best practices, research and other PCK communities. When teachers acquired this knowledge for transforming content-knowledge in particulate nature of matter, the knowledge which they reflected through questionnaires is positioned within pPCK in the topic of intervention. Finally, when teachers were observed as enacting the acquired pPCK, the enactment at this point is located within the ePCK at Topic-Specific level.

2.10 Conclusion

In this chapter, the key principle presented towards a suitable conceptual framework was informed by the transformation of content knowledge into a teachable form. The framework of TSPCK has been chosen deliberately because it engages teachers' content knowledge. Shulman (1987) argues that the thinking and planning of a teacher is as good as the enactment of that planning into classroom practice. In this study, some of the teachers were followed to their classroom to observe how the knowledge acquired through the intervention impacted OFTs' classroom practice.

In a study by Mavhunga and Rollnick (2013), pre-service teachers were able to fast-track their TSPCK after exposure to the framework. In a study by Pitjeng-Mosabala and Rollnick, (2018), unqualified graduate teachers' content knowledge and TSPCK improved significantly after a TSPCK based intervention was conducted. The framework of TSPCK engages teachers' content knowledge simultaneously with the teaching of that content thereof. These are both crucial attributes which might be of need in a case of teachers who are teaching content areas which are out of their field of expertise.

A thorough review of the phenomenon of out-of-field teaching as well Teacher Professional Development programmes and difficulties of learning the topic of particulate nature of matter were presented in this chapter. The lack of content knowledge in out-of-field teachers informed the need for a theoretical framework to improve not only their content knowledge but also their ability to transform their Content Knowledge into a teachable form. In this chapter, literature has been presented on teacher education and focused on the broader concept of PCK and TSPCK at a Topic-Specific level. In the next chapter, the entire research methodology of this study, data collection methods and analysis are presented. The quality of data and ethical considerations of this study were also presented in detail in the chapter following.

CHAPTER 3

RESEARCH DESIGN AND METHODOLOGY

Mixed methods research has increasingly gained significance in many science education research studies over the past few decades. In this chapter, the methodology used in the study is described. The methodology links to the conceptual framework and how it was chosen to best answer the research questions. The methods used to shape and collect data and the reasoning behind the choice of these methods are discussed. This chapter describes the data collection process, sample selection of participants and the adaptation and validation of the research instruments used to collect the data. To conclude the chapter, ethics and measures of quality of data are discussed.

3.1 Introduction

This study was aimed at investigating the impact of an intervention with an explicit focus on TSPCK to improve CK, TSPCK and eTSPCK of out-of-field teachers in the topic of the particulate nature of matter. In responding to research questions posed by this study, the paradigm of pragmatism informed the research design of the study as given in Figure 3.1.

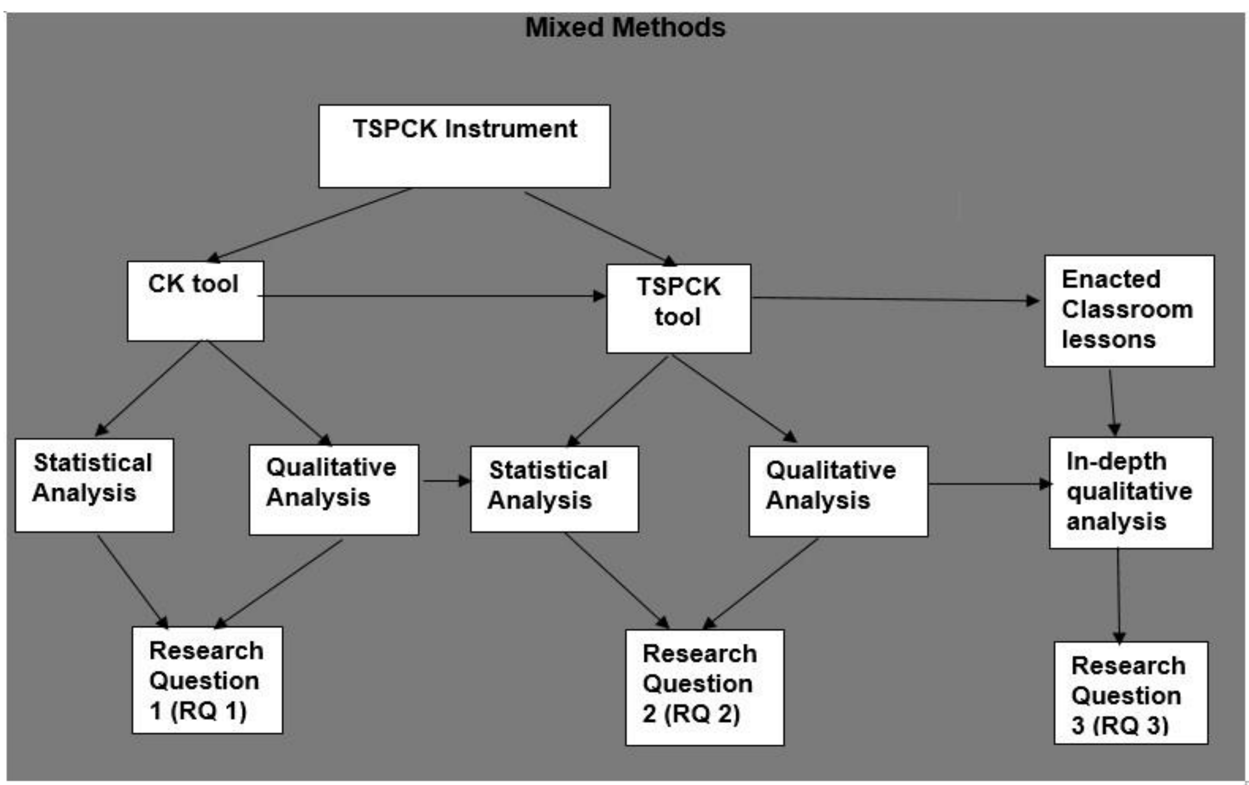


Figure 3.1: Outline of the research design

The nature of TSPCK is a multi-faceted construct. A range of methods was implemented to reach deeper meanings at each of these different layers of TSPCK. A validated TSPCK instrument was used to measure the impact of a signature intervention on the content knowledge, quality of TSPCK and eTSPCK of out-of-field teachers before and after the intervention. The design of the TSPCK instrument is such that it consists of a CK tool and a PCK tool in the particulate nature of matter.

Firstly, the impact of the intervention on the content knowledge of out-of-field teachers was measured using the CK tool of the TSPCK instrument in the particulate nature of matter topic before and after the intervention. Data at this stage was used to respond to the first research question. While the intervention was not on content knowledge but TSPCK, content knowledge is pre-requisite knowledge for the development of TSPCK. Secondly, the impact of the intervention on the quality of TSPCK was measured using a validated TSPCK instrument in the particulate nature of matter and the data generated at this stage was used to respond to the second research question. Finally, teachers were observed while delivering their enacted lessons in a classroom to further investigate the impact of the intervention on the quality of their eTSPCK. The evidence arising from their classroom practice was used to respond to the third research question.

In the first aspect of the research design, the CK tool of the TSPCK instrument was administered to a cohort of fifteen out-of-field teachers (N = 15) before and after the intervention. The qualitative teacher responses gathered from the CK tool were converted into quantitative data using a memorandum (see Appendix 6) and Rasch analysis was used to further analyse the emerging patterns from the scores generated through the memorandum. Similarly, the TSPCK tool was administered to a cohort of fifteen out-of-field teachers (N = 15) before and after the intervention. The qualitative teacher responses gathered from the tool were scored and converted into qualitative data using a designed and validated rubric which was later subjected to Rasch analysis.

Lastly, for the impact of the intervention on eTSPCK in the particulate nature of matter, the video-recorded lessons were analyzed using in-depth qualitative analysis. In the introductory section above, the overall research design is presented, illustrating the rationale behind the choice of mixed methods. The data collection methods, sample and data analysis are presented in the section below.

3.2 Research Methodology

3.2.1 Mixed Method

Mixed methods (MM) is emerging as a significant research approach in science education (Guetterman, Fetters, & Creswell, 2015). This research method has gained more popularity specifically within PCK research due to the tacit nature of PCK (Kind, 2009; Aydeniz & Kirbulut, 2011). MM is known as a research design which combines both quantitative and qualitative research for collecting and analyzing data in a single study (Mayoh & Onwuegbuzie, 2015). Instead of being loyal to either quantitative or qualitative research approaches, MM looks beyond such loyalties and sees the world, not as absolutely quantitative or qualitative but rather a mixed world. MM seeks to find the most holistic depiction of reality rather than looking at the weaknesses and strengths of qualitative and quantitative research paradigms in isolation.

Some researchers view this research approach as one which is largely located in post-positivism (Taylor & Medina, 2013). According to Cohen, Manion, and Morrison (2013), post-positivist theories informing MM are based on the belief that beyond the linear process of cause and effect, results are made up of a complex collection of causative factors interacting with each other. Thus, theories of post-positivism assume that multi-perspectives and arguments are brought together in a multi-layered world which should be tolerant to multiple interpretations.

While there are some inferences of MM having its roots located within post-positivism theories, in the case of this study MM is understood as premised within pragmatic paradigm (Mertens, 2014). This implies that MM employs both meaning interpretations as well as neo-scientific approaches in a single study. Pragmatism has its worldview based on a practice-driven world where practical consequences and real effects are deemed as crucial constituents of meaning and truth that we make of the world (Venkatesh, Brown, & Bala, 2013). MM argues that there might be both singular and multiple versions of truth and reality, which may be objective or subjective, scientific or humanistic.

The benefits of using MM are that it rather focuses on what is perceived as most appropriate and relevant in responding to research questions and this aspect is the most useful in understanding the phenomenon of interest. MM enables researchers to identify and rectify errors which might arise from the use of single approaches. It enables deeper insights and meanings emanating from data to be further probed. MM allows richer data to be collected and new modes of thinking to emerge where inconsistencies between two individual data sources are found.

Investigating a tacit construct such as TSPCK can be tricky in that TSPCK is the transformation of several components into different forms for effective teaching in a specific topic in science. It is not easy to measure this construct using one method. It requires a variety of methods to get broader insights into the investigation (Aydin, Friedrichsen, Boz, & Hanuscin, 2014). For example, TSPCK involves the thinking that happens in a teacher's mind when planning to teach and actual enactment and deliberating in a classroom; that is planned TSPCK and enacted TSPCK. TSPCK is widely characterized as arising from the knowledge of five components, specifically the interactive use of these components in formulating explanations by teachers (Mavhunga & Rollnick, 2013). While writing these components, they might come across as linear or as having a chronological order but practically they are integrated into several scenes of classroom practice. The concept of TSPCK presents a multi-layered construct which consists of an array of knowledge components interacting with one another to bring into light the level of TSPCK that teachers possess. MM is one way that acknowledges that such a construct with multi-warrants like TSPCK might be best understood through the pluralist method than mere allegiances with one method.

There are however, limitations associated with every research method and mixed methods are not exempted from having limitations. Creswell (2014) argues that one of the limitations of MM is that it is difficult and challenging to learn and apply both qualitative and quantitative methods at the same time. As a result, MM takes more time both at the beginning and end of the study because a researcher must first understand this research method from the pre-planning and proposal stages of the study. The researcher also needs to come to a consensus about how the findings fit together or not and establish the meaning of these results at the end of the study. Most of the challenges encountered in using this method are due to the integration of results as data sets that are often not compatible for analysis which might cause discrepancies and as such result in unequal evidence within a study.

This inequality normally is due to unequal priority given to each method causing bias in favor of one method. In addressing the issues arising from the use of MM, priority, implementation and integration were considered important factors that literature regard as key when undertaking MM research (Wisdom, Cavaleri, Onwuegbuzie, & Green, 2012; Fetters, Curry, & Creswell, 2013; Guetterman et al., 2015). Firstly, the researcher had to decide on the prioritisation of each of the mono-method in the study, whether both quantitative and qualitative were given equal weightings when collecting and analysing data at the different points (Wisdom, Cavaleri, Onwuegbuzie, & Green, 2012). In this study both these research methods were used at almost each point and held equal weightings throughout the study.

The second factor was implementation and this step guides the application of either quantitative or qualitative methods in the research study. This factor determined whether qualitative and quantitative method were implemented at almost same point in time (concurrent) or one was implemented after the other (sequential) (Guetterman et al., 2015). This implied that a researcher could choose to implement the traditionally mono-methods in a fully mixed design or opt to implement partially mixed design, depending on the option which best answers research questions. Cohen et al (2013) argue that fully mixed design represents the highest order of mixing quantitative and qualitative methods. In this study, fully mixed design concurrent equal status design was found best suitable in addressing the research questions. This meant the integration of these two traditionally mono-methods occurred simultaneously since both held equal weights. Thirdly, the kind of integration chosen looked at convergence in data to be able to receive more reliable data inferences in the study.

As indicated earlier that due to tacit nature of PCK construct with multifaceted aspects, different methods were integrated to reach deeper meanings at each of these different layers of TSPCK. For example, to study the impact of the intervention data was collected through written responses from CK and TSPCK tools and verbal enactment of lessons through video recordings. Narrative qualitative method strategies were applied to capture and analyse the shifts observed in OFTs' TSPCK as a result of the intervention. However, statistical quantitative methods were applied in the same data to develop understanding of the extent of the observed shifts before and after the intervention. This is how different aspects of the same research question were best answered by analyzing and integrating the findings of the different traditional methods not reflected by the other, thus applying equal weighting on both methods. The research question on the impact of the intervention in OFTs' eTSPCK was best reflected through descriptive qualitative methods. In the discussion above, both qualitative and quantitative methods did not follow a chronological order with one strand emerging from, or following, the other which was a sign that the study followed fully mixed design with concurrent equal status to address the research questions (Cohen et al., 2013).

According to Creswell (2014), research should be driven by research questions that should dictate the methodology that has a high probability of providing clear understanding in answering the research questions whether it's qualitative or quantitative. For example, the guiding research questions for this study were as follows: What is the impact of an intervention with an explicit focus on TSPCK on the quality of teacher knowledge and classroom practice of Natural Sciences teachers, teaching out-of-field of expertise?

To answer this question adequately, three sub-questions were formulated:

1. What is the impact of the intervention on the OFTs' content knowledge in the topic of the particulate nature of matter?
2. What impact does the intervention have on the quality of the OFTs' TSPCK in the topic of the particulate nature of matter?
3. What impact does the intervention have on the quality of the OFTs' eTSPCK in the topic of the particulate nature of matter?

The power of TSPCK lies not only in the manner in which teachers use this construct to plan and reason about their content knowledge but also in the manner teachers use this knowledge in classroom practice. This is well articulated through the RCM model which has established a link between the knowledge that a teacher has in a specific topic and enactment of that knowledge in classroom practice (Carlson & Daehler, 2019). The research questions, therefore, must talk to the nature of this construct in both the planning to teach and the enactment level. The nature of TSPCK has multi-warrants attributing to its' existence. Thus, it is only reasonable to implement multi-methods to reach into deeper meanings at each of these different layers of TSPCK hence the mixed-methods approach was used. For example, research questions posed in this study talk to an investigation of the 'impact' that the intervention would have on OFTs' CK, TSPCK and eTSPCK. Overall, the research questions suggest that the study will be revolving around the impact of the intervention in teachers' knowledge and classroom practice.

3.2.1 Case study approach

The case studies can be defined as empirical enquiries, which investigate a single phenomenon within its real-life context. Merriam and Tisdell (2015) defined a case study as 'an intensive, holistic description and analysis of a single instance, phenomenon, or social unit. Eisenhardt (1989) defines a case study as a 'research strategy which focuses on understanding the dynamics present in a single setting'. Several researchers highlight the importance of setting a case within its context. As a result, context is one main feature of a case study. Yin (2013) argues that central to factors which qualify a case study lies on 'delimiting the object of study and this delimiting is often referred to as 'bounded system or 'integrated system. Therefore, there must be bounded-ness or boundaries in the topic of research whether it bounded by a limited number of participants or limited amount of time for observations but if there are no bounding factors it is not a case. Thus, context and boundary were main features which comprised this case study.

Complex social activities such as the learning of practicing teachers can be best understood by a case study because it offers numerous variables that might be critical in understanding the social unit under investigation. This might in return result in a rich description of the case. In this study, a case study has been used to investigate the impact of TSPCK to improve CK, TSPCK and eTSPCK in the development of out-of-field Natural Sciences teachers. The context that is referred to implies that multi-sources of evidence that provide descriptions and details are necessary to strengthen a case study (Crowe et al., 2011). It is upon the convergence of different data sources and evidence emerging from one study that a case study becomes valid. For example, the tools which were used to collect evidence of TSPCK knowledge in out-of-field teachers were scored using a rubric. The rubric ranged from limited (1) to exemplary scale (4), which implies that the researcher analyses the descriptions that teachers provide and fit them within the rubric descriptions. If the analysis of the teacher responses were only shedding light through qualitative analysis in this case study, this method alone would not be able to shed light on the difficulty of moving from one level to the next. The rubric is not able to distinguish the levels of difficulty with categories of TSPCK but statistical difficulty measure is used to establish this knowledge. In this example, two methods were employed to measure one data set and these convergences were examined to strengthen this case study.

Secondly, the participants of this case were bounded by the fact that they are permanent employees of the department of education in the Eastern Cape, who were teaching Natural Sciences without any formal background to teach chemistry and also not qualified to teach high school grades. However, they were expected to attend cluster meetings at least once in a term in a specific college in Mthatha to help them add to their content knowledge. These are factors which made them a bounded system. Thus, case study was found to be the most relevant research strategy for this particular study.

The benefits embedded in this research strategy include an opportunity to get deeper insights into the phenomenon through different data sources as mentioned above. In the previous section of methods used in this study, MM was employed. The research methodology and strategy used in this study are in harmony with each other and seek to provide deeper insights and more clarity on the phenomenon under study through different data sources.

Cohen et al. (2013) argue that case studies are a prototypical instance of mixed methods research in that they seek to explain, describe, illustrate and enlighten. Case studies obtain these attributes through various data collection tools which seek to capture various variables which are at play in a particular situation. The kind of study undertaken fitted very well as a case study because it sought to understand a real-life situation in which rural out-of-field science teachers face. Literature accepts and recognizes that such teachers lack content knowledge and tend to possess shallow approaches to teaching. The purpose of this study was to investigate a case where such teachers could be exposed to a signature intervention to improve their TSPCK in the particulate nature of matter as means to provide a model which could be used to fast track their development in understanding the founding concepts in the particulate nature of matter. The particulate nature of matter is the topic which was used to conduct this intervention due to the nature of Topic-Specific PCK. In the previous paragraphs above, literature has highlighted context as an important feature in which a case should be set. In the same effort, thick descriptions and details were provided as evidence of how CK, TSPCK and eTSPCK of OFTs improved as a result of exposure to the intervention.

The out-of-field Teachers (OFTs) develop their knowledge of CK and TSPCK when exposed in a TSPCK based intervention. Several tools of data collection such as CK tools, TSPCK tools and classroom observations were all used to understand shifts in knowledge before and after exposure to the intervention. The study also acknowledged that there are several variables which might be operating in that development which the study is investigating. It acknowledged that the manner in which the intervention might impact OFTs knowledge would not only depend on the shifts in their TSPCK but also their eTSPCK and CK in the topic of the intervention. Thus, several tools had to be used to collect evidence to build up this case and therefore the study indeed fits best with the case study as a research strategy. However, there are limitations associated with case studies. Due to the nature of case studies which tends to focus on a specific context within specific set boundaries, it becomes a challenge to generalize findings from such studies as its case has its specific context and boundaries. However, due to thick descriptions and in-depth nature of case studies, the findings of a case study can be used in another case with similar context. For example, the findings of this study may be very useful in further understanding ways of improving teacher professional knowledge of CK, TSPCK and eTSPCK for OFTs as there is also little research done in this area in South Africa.

3.3 Data Collection methods

The use of mixed methods implies that various data collection tools were deployed to collect quantitative and qualitative data. Data was collected using designed and validated questionnaires that were adapted from senior secondary level to suit expected learner knowledge which participants of this study were teaching (Junior Secondary level). The mixed-methods approach was used to transform data collected into numerical clusters and analysed quantitatively. Video-recorded lessons were used as data sources for qualitative data analysis of classroom practice. Additionally, CoRes were used to analyse teachers' knowledge later in the intervention while interviews were used as additional data for a video-recorded classroom lesson. WhatsApp messages were used as additional data for the support offered to teachers beyond face-to-face intervention.

3.3.1 Questionnaires

The study used a survey method to conduct the investigation. Many researchers have used questionnaires to conduct their research (Mavhunga & Rollnick, 2013; Park, Jang, Chen, & Jung, 2011; Tepner & Dollny, 2012). According to Cohen, Manion and Morrison (2013), surveys are useful for gathering factual information, data on attitudes and preferences, beliefs and predictions, opinions, behaviors and experiences. In particular, the aim of this study was to collect data on the ability of OFTs to transform their CK into a specific topic into a form which makes it suitable for teaching. Even though it is a challenge to ensure that participants would understand all questions and scenarios posed to them in the same way, instruments such as the one developed to assess teachers' Topic Specific PCK in the particulate nature of matter are useful in that they can be administered to large groups of teachers. The design of the questions tried as far as possible to take into consideration the disadvantages posed by using instruments to gather data. Two different kinds of pencil and paper tools were used as one of the core research tools in this study. The first measured the quality of TSPCK in the particulate nature of matter and the second tool focused on the achievement of CK.

3.3.2 Video-recorded classroom lessons

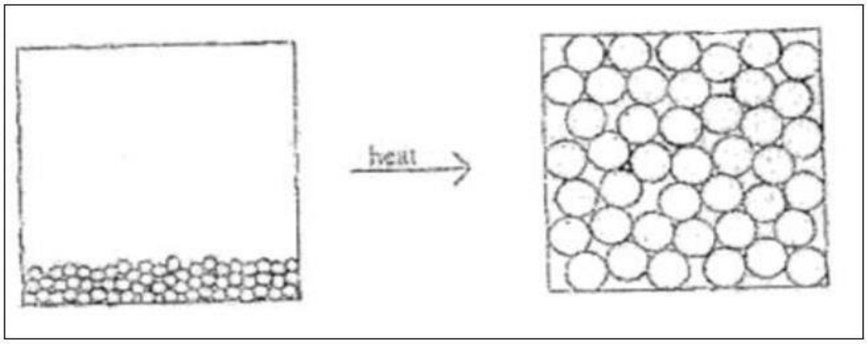
Video-recordings have been widely used in qualitative studies as a data collection method (Latvala, Vuokila-Oikkoonen & Janhonen, 2000). It is argued that observing human behavior can be selective as participant's observations without videotape might be influenced by feelings, attitudes and values. One of the key advantages of this data collection method is that video recordings do not evaluate the reality under study but capture the same behaviors and contents as those in reality. Key to videotaping data method is the density of data and permanence. Moreover, this method allows a thorough in-depth analysis as events can be repeated unlimitedly, for example, one can fast forward and playback a video recording. This data collection method also allows access to all verbal and non-verbal behaviours that cannot be possible to capture through human observations alone. Videotaping minimizes subjectivity and results in a more objective presentation of the phenomenon under study. In this study, Videos were used to collect data on teachers' TSPCK before and after the intervention to assess the impact of the intervention on the quality of the OFTs' eTSPCK before and after the intervention.

3.3.3 Adaptation of questionnaires

- **TSPCK Tool**

The TSPCK tool in the particulate nature of matter is designed to have five categories that match the five components of the TSPCK construct. The TSPCK questionnaire was based on the knowledge components of TSPCK in the Mavhunga and Rollnick (2013) model, namely students' prior knowledge, curricular saliency, what makes a topic difficult to teach, representations and conceptual instructional strategies. The tool was validated and used in a study to measure the quality of TSPCK of novice unqualified graduate teachers (Pitjeng, 2014). (See Appendix 2 for the full original TSPCK tool). The questionnaire is designed in a way that the TSPCK parts of the questionnaire compel teachers to think and reason their CK in relation to the students. The questionnaire is designed specifically based on teacher tasks that produced teacher responses about the five knowledge components of TSPCK. For example, under the first category, the items seek to probe for learner prior knowledge by identifying common misconceptions learners have in particulate nature of matter.

1. Learners in a grade 8 class were asked to represent the change that takes place when a substance is heated. The response Thabo has written on the board is shown below.



How would you comment on Thabo's response as part of an explanation to the rest of the class?

Figure 3.2: Question probing Learner Misconceptions

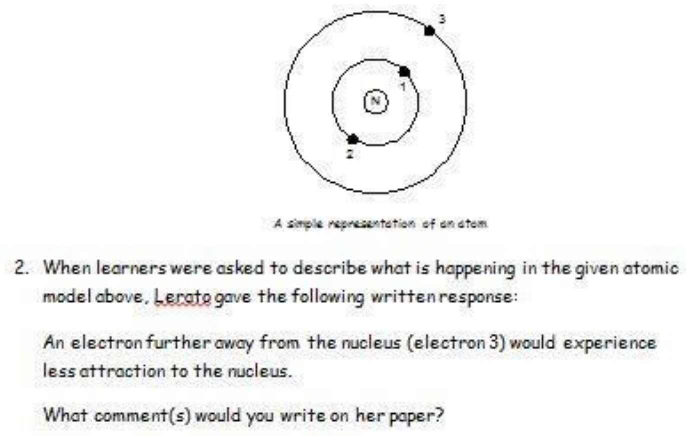
However, the TSPCK instruments had to be adapted to suit the context of the sample under this study. The process of adapting both TSPCK and CK tools included a reference team which comprised of two content specialists practising at Wits University. The two content specialists were chosen based on their experience with regards to the TSPCK construct and school curriculum at large. One of the expert teachers teaching Junior Secondary level was also consulted in ensuring that the material used was aligned with the current CAPS document at GET level. The TSPCK instrument was originally designed for Grade 10 teachers and specifically curriculum coverage at Grade 10 level. Therefore, some of the items were found not suitable for the development of CK and TSPCK for out-of-field Natural Sciences Teachers within Junior secondary level specifically focusing at Grade 8. Table 3.1 outlines the curriculum that Grade 8 teachers are expected to cover and is compared to what the curriculum at Grade 10 expects teachers at that level to cover; thus, the need to edit the original instrument to make it suitable for Grade 8 teachers.

Table 3.1: Grade 8 curriculum according to CAPS document

Content and concepts covered by PNOM as per Curriculum at GET Level, (Grade 8 level)	**Currently the TSPCK instrument covers the following concepts**
Matter and Materials • The concepts of the particle model of matter (all matter is made up of particles called atoms & molecules), • Explaining properties of solids, liquids and gases and the process of diffusion in liquids and gases.	**Matter & Classification** • Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity. • Mixtures (heterogeneous mixtures and homogenous mixtures) • Pure substances: elements and compounds
• Change of state according to PMOM (melting, evaporating or boiling, condensing, freezing and solidifying)	State of matter & Kinetic Molecular Theory • Three states of matter • Kinetic Molecular Theory
• Density, mass and volume (Mass, Volume), Density and states of matter, density of different materials (floating and sinking)	Atomic Structure • Structure of matter • Isotope
• Expansion and contraction (matter expands when heated, matter contracts when cooled)	
• Pressure (how gases respond to pressure and ways to increase pressure in gases)	

From Table 3.1, the focus is put on different concepts of matter at Junior Secondary level and Grade 10 level. The emphasis at Junior Secondary level is on the interpretations of particle behaviour through various physical phenomena.

The following two items were extracted from both the original TSPCK instrument and the TSPCK instrument adapted to suit the context of the teachers under study as indicated in the Figure 3.3. As indicated in Table 3.1 above, the curriculum at Grade 8 level chemistry only requires learners to understand the atom and know the different types of sub-atomic particles without the detail of atomic structure and isotopes. It is for these reasons that these items were replaced with relevant concepts within Grade 8 level (Refer to Appendix 3 for a fully adapted instrument).



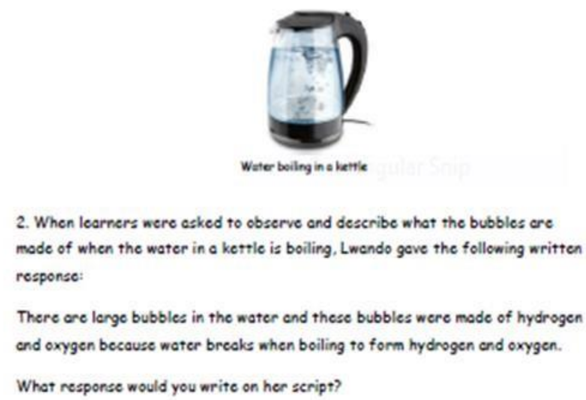


Figure 3 3: Items from old and new TSPCK instruments

- **Adaptation of the CK Tool**

The original CK questionnaire was constructed based on the content presented in a range of textbooks for Grade 10 Physical Sciences. The concepts were chosen according to concepts perceived as big ideas in the topic of particulate nature of matter. These highlights are key concepts commonly viewed by practitioners as important for students to learn to understand the topic (Loughran, Berry, & Mulhall, 2004). The test covered five aspects of particulate nature of matter which included

- Pure substances, mixtures, atoms and molecules
- States of matter represented by drawings of microscopic representations
- Kinetic molecular theory
- Atom and its basic structure
- Isotopes (Pitjeng, 2014)

While the questionnaire was for teachers, it was based on expected learner knowledge as these teachers were teaching Junior Secondary learners; hence, the CK instrument had to be adapted to accommodate concepts covered at this level as defined in the TSPCK instrument above. Figure 3.4 is evidence of the CK items which had to be replaced and the new items which were added. While the concepts listed above were drawn from various sources used at Grade 10 physical sciences level, these concepts were also found to be used at the GET natural sciences level, except for isotopes. This resulted in the removal of items that could probe for teachers' understanding for isotopes from the instrument. These were replaced with items which were within the scope of Junior Secondary level content in the particulate nature of matter. At this level, the concept of particulate nature of matter only revolves around pure substances, mixtures, atoms, molecules, states of matter represented by sub-microscopic representations, kinetic molecular theory and a basic introduction to the atom and its basic structure. Thus, the concept of isotopes is only covered from Grade 10 and therefore it was replaced with Junior Secondary level concepts as it is not part of the level targeted by this study. The Figure 3.4 shows two items extracted from both the old and newly adapted instrument. The item in the first column A was used to replace the item in the second column B.

A. Item from newly adapted tool	B. Item from the old tool

A. Item from newly adapted tool

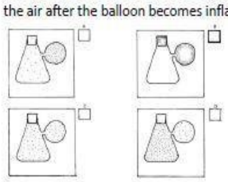
5.

(a) Name the sub-atomic particles found in the nucleus of an atom

____

(b) A flask containing air was connected to rubber balloon. Then the air in the flask was heated with a flame and the balloon inflated.

Place an X in the square next to the drawing which you think is the best description of the air after the balloon becomes inflated.



(c) After many experiments, scientists now think all substances are made up of particles. Use this idea to answer the question below:
A block of ice is taken out of a freezer at -100°C. Describe what happens to its particles as its temperature rises to -10°C. Draw a diagram to explain what you mean.

B. Item from the old tool

5.

(a) Name the sub-atomic particles found in the nucleus of an atom?

____

(b) What type of charge is found on each of the above mentioned sub-atomic particles?

____

(c) Fill in the blanks on the following table.

Element	Notation	Atomic number	Mass number	Number of protons	Number of electrons	Number of neutrons	Number of nucleons
				20	18		
Fluoride ion	$^{19}_{9}F^{-}$						
	$^{23}_{13}Al^{3+}$						
				17	18		

(d) Which of the following unidentified elements are isotopes of one another?
$^{12}_{6}X$, $^{12}_{7}Y$, $^{24}_{12}A$, $^{14}_{6}Xy$, $^{13}_{6}Mp$ (note: X, Y, A, Xy and Mp represent the symbols of unspecified elements).

____

How did you work out the answer above?

____

What is the name of an isotopic element represented in (d)?

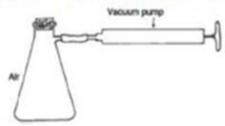
____

(d) After many experiments, scientists now think that:

- All things are made of small particle
- These particles move in all directions
- Temperature affects the speed they move
- They exert forces on each other

Use any of these ideas to help answer the following question:
A football is pumped up during the day when it is warm. In the evening when the temperature falls, the football does not feel so hard.
How does this happen? (Assume the football does not leak)

(e) A one-litre flask containing air and a hand evacuating pump were shown, and the operation and function of the pump were demonstrated. The pump was then connected and operated for a few seconds in order to remove some air from the flask.



Suppose that you had magic eye glasses with which you were able to see the air in the flask. Draw how it would look before and after the vacuum pump was used to remove some of the air.

(e) Chlorine consists of two isotopes ^{37}Cl and ^{35}Cl. The average atomic mass of naturally occurring chlorine is 35,5amu. Which of the following percentages of the two isotopes is most likely in naturally occurring chlorine? **Justify your choice**

	% ^{35}Cl	% ^{37}Cl
A	50	50
B	67	33
C	33	67
D	99	1

Figure 3.4: Example of item from old tool and newly adapted tool

- **Validity and reliability of the newly adapted TSPCK instruments**

As alluded to in the discussions above, the TSPCK instruments adapted in this study were validated and checked for reliability in a separate study. However, when the newly adapted instruments were administered to the out-of-field teachers, these were subjected to Rasch statistical analysis. The findings from Rasch analysis happened to be valid and reliable (see chapters 5 and 6) which validated the instrument.

3.3.4 Interviews

Interviews are commonly used in qualitative studies as a data collection method that provides deeper insights into understanding perceptions, meanings, and definitions of situations and construction of reality. In this study, the method allowed the researcher to access insights into thinking and reasoning behind classroom actions and what they were planning to do in their lessons. There are two kinds of interviews; structured and semi-structured interviews. In this study, semi-structured interviews were used. There are different modes of administration that can be used to conduct semi-structured interviews which are written questionnaires, electronically, face-to-face and over telephone. The mode of administration used for this study was face-to-face mode. There are various advantages for using interviews, firstly face-to-face interviews mean that the researcher or interviewer can be present and be able to use verbal and non-verbal communication. The presence of the interviewer is also perceived as the ethical way of conducting research because the interviewer is available to clarify questions when participants seem confused or unclear (McIntosh & Morse, 2015). The interviewer can immediately use unscheduled prompts that will help participants elaborate their responses where necessary. Most importantly, when the interviewer is present it means when participants are not comfortable or unease about the interview, the interviewer would be able to provide emotional support or offer a break. The disadvantages of face-to-face interviews include the fact that participants could feel obligated to give socially desirable answers when sensitive issues are questioned (McIntosh & Morse, 2015). During face-to-face interviews, the presence of the interviewer has an affect in the responses given. The challenges associated with these were addressed by using more data collection methods such as TSPCK instruments, video-recorded lessons. Additionally, interviews were rather used as additional data to get deeper insight about the transformation components of the TSPCK.

3.3.5 WhatsApp

In this study, electronic media was used as a platform for sustained classroom support. A WhatsApp chat group (Church & de Oliveira, 2013) was initiated to enable ease of loading document as attachments and photos that all become available instantly. This platform was meant for participants to place request or assistance on specific concepts where they could take a snapshot of the board or lesson plan for comments. Comments would then come from the participants and the researcher as additional support. This kind of support was informed by an acknowledgement that translating the TSPCK into practice is not an automatic occurrence, therefore teachers need to be constantly reminded about each of the components of the TSPCK. Furthermore supported continuity of the discussions that were initially made during the intervention was considered important, as Main and Pendergast (2015) attest for the sustainability of newly learnt competence through the elongated continuity of the discussion of the same aspect.

3.4 Participants

The participants in this study were practising teachers at Junior Secondary schools in rural schools of the Eastern Cape teaching Grade 7, 8 and 9. The majority of teachers who participated in this study are teachers who were trained under the old governing system prior to 1994. About 80% of the sample had either Junior or Senior Primary Teachers' Diploma as their undergraduate qualifications. About 87% of these teachers had 20 years and above of teaching experience of all subjects in primary school and only had 2- to 3-years of experience in teaching Natural Sciences at different from Grade 7 - 9. The majority of the schools to which these teachers were teaching in started from Grade R – Grade 9 and these schools are called Junior Secondary School.

Currently, teaching is an all-graduate profession with a minimum requirement of 4 years of training for both primary and secondary level (Rollnick & Mavhunga, 2016). According to Reeves and Robinson (2011), a qualified teacher must at least have a recognized Relative Education Qualification Value of level 14 (REQV 14) which means Senior Certificate plus four years of University training In the South African education system, this changed from 2 years post-school training for both primary and secondary teachers (Rollnick & Mavhunga, 2016). In the Table 3.2 provided is the demographic data of the participants which has teachers' primary qualifications, number of years teaching all primary school subjects and their number of years teaching Natural Sciences.

Table 3.2: Teaching profiles of the Natural Sciences Teachers

Teacher	Qualification	Number of years teaching all primary subjects	Number of years teaching NS
1. Mary	NPDE	16	2
2. Noreen	SPTD	24	3
3. Harriet	JPTD	18	4
4. Amanda	JPTD	24	2
5. Sophie	SPTD	16	2
6. Antana	PTD	21	3
7. Merriam	SPTD	25	2
8. Nosipho	PTC	30	8
9. Nicky	STD	30	1
10. Noxy	SPTD	25	3
11. Thabo	BEd	0	1
12. Andile	BEd	16	2
13. Litha	SPED	14	2
14. Fiona	SPTD	14	3
15. Zukie	SPTD	15	2

In Table 3.2, some teachers had teachers' certificates such as the Primary Teacher's Certificate (PTC). PTC is an outdated two-year professional teaching qualification which according to the new norms and standards for educators is equivalent to REQV 11 or 12 depending on whether the teacher possessed a senior certificate or not. Some teachers had a National Professional Diploma in Education (NPDE). NPDE was a programme meant to upgrade teachers with two-year qualifications to REQV 13. The majority of teachers had Teachers' Diploma had as SPTD (Senior Primary Teachers' Diploma), Junior Primary Teachers' Diploma (JPTD) and Secondary Teachers' Diploma (STD) which are all outdated 2-3-year qualifications that were offered in former colleges of education for black students as indicated in Table 3.2. These diplomas were assessed as REQV 13. While the majority of these teachers were offered opportunities to upgrade their qualifications through BEd Honors, these teachers were never trained as high school science teachers even upon their upgrading certificates. They are trained as Primary school teachers. The sample comprised of the GET teachers from ten regions under a particular district of the Eastern Cape Province. The schools chosen were roughly 20-100 km apart from each other. Fifteen teachers were exposed to the TSPCK based intervention but before the intervention, three teachers were assessed in their classrooms and again after the intervention. The three teachers chosen were roughly 40-80 km apart and were chosen based on their willingness to participate throughout the study and their availability.

The teachers in Table 3.2 attended workshops at a specific college in the Eastern Cape; however, the institution is now operating as regional offices of the department of education under a particular district. The facilitators of these workshops are teachers who are appointed based on their level of enthusiasm. These teachers are themselves 'out-of-field' teachers who have improved their content understanding through attending a series of workshops provided by the department. The professional development networks are specifically focusing on improving the content knowledge of teachers in Natural Sciences by discussing the concepts in the school textbooks. The programmes are such that the facilitator teachers teach topics to be taught in a term over 1-2-day workshops.

- **Sample**

The type of sample for this study was a sample of convenience since while the study focused on the particular group defined above, the results did not represent a wider population but the group that was involved in the study. These teachers were bound with similar factors such as having no formal qualification in chemistry. They depended majorly on the department's workshops to bridge the gaps in their content understanding.

However, Eastern Cape Province is a largely rural-based Province with the population widely spaced. Schools are commonly over 100 km from each other even though they fall under the same district and cluster. It is argued that under such factors there could be constraints that make it impossible and impractical to select such participants randomly and spend an inordinate time travelling about before testing the sample (Cohen, Manion, & Morrison, 2011). Therefore, the sampling strategy used to select the subset of three of the OFTs was cluster sampling which was opted for based on the geographical proximity of the schools in which the entire cohort teach. Also, the physical accessibility to the schools such as road infrastructure availability and ease of ground terrain were considered facts in opting for cluster sampling. Cluster sampling provides the researcher with a choice to select a specific number of geographically close schools. In this study, proximity and accessibility were realistic factors that influenced sampling as well as a constraint in the total number of the OFTs who could attend the intervention. Most importantly, was the ethical consideration for voluntary participation of the participants in a cluster in alignment with the ethical protocol.

Additionally, the three selected teachers happened to be average teachers and in the middle of the group rather than the top of the range, which meant the choice, was not going to distort the results. This meant the study was looking at a good example of what was taken up by out-of-field teachers.

3.5. Brief Description of Signature Intervention

The approach used to carry out the intervention in this study simulated those from a science education methodology class from a specific university in South Africa and these interventions are called signature interventions. A key characteristic of these interventions is a strong focus on developing the TSPCK in core topics of Life Sciences, Physical Sciences and Natural Sciences (Mavhunga & Rollnick, 2017). The focus of explicit PCK in core topics is exposing pre-service teachers to the idea of transformation of content knowledge in specific topics arguing that pedagogical transformation of content emerges from the five components of PCK in specific topics. These five components of TSPCK were discussed in detail in chapter 2.

There were three reasons for this particular University to implement the PCK in these science education methodology courses. Firstly, their interest was to ensure that this university produces graduate science teachers who have specialized knowledge of core topics in the discipline of Natural Sciences and their major stream (Physical Sciences or Life Sciences). Secondly, the implementation of the PCK ensures that the graduate teachers understand the transformation of their comprehended concepts and placed learners at the center in their planning and choice of pedagogical approaches. Lastly, these courses aim at producing graduate teachers who know how to pedagogically transform comprehended knowledge when engaged in planning and teaching a new topic.

Drawing from these key aspects of the signature interventions from this University's science education methodology courses, a similar intervention was implemented with a group of 15 out-of-field science teachers. In this study, a signature, intervention with an explicit focus on developing their PCK in a specific topic of Natural Sciences was implemented with teachers who were teaching chemistry out-of-field through a five-day workshop. The understanding of the TSPCK, as well as five knowledge components from which the transformation of the CK emerges, were explicitly explained. The aim was to expose out-of-field teachers to ways of planning their lessons using the TSPCK construct.

Therefore, teachers were exposed to all five components of the TSPCK in the particulate nature of matter daily, in a step by step process to introduce them to knowledge components which can assist them in planning and teaching a specific topic.

Similarly, science methodology courses informing the approach of this intervention, the acquired knowledge of TSPCK in the particulate nature of matter was captured and measured through specially designed and validated TSPCK instrument. The TSPCK instrument consists of the five knowledge components of the transformation of content knowledge with tasks and scenarios that make the tacit TSPCK of teachers, explicit.

It is argued that the quality of theTSPCK is mirrored by an understanding of each of the TSPCK components and its interaction with others (Mavhunga & Rollnick, 2016) and this was the key aspect analysed in teachers' TSPCK instruments and classroom teaching. These tools gave a window into the quality of the TSPCK of the OFTs at different points of the intervention. Modified CoRes were used to reflect explicit prompts of the TSPCK components. A subset of three teachers were followed to classroom and the acquired knowledge in a planning to teach context was assessed in real classroom practice. The conceptual framework of this study acknowledges the continuum found in the three developmental realms of PCK (cPCK, pPCK and ePCK) as reflecting discipline, topic and concept specific grain sizes. The PCK focused on at this stage of the study is context-free, shared by several scholars and teacher education programmes in science education, and thus, premised within cPCK in the particulate nature of matter. The details of the intervention will be expanded in chapters following.

3.6. Data collection

There were three sets of data collected within each set being administered before and after the intervention. The rationale behind these three data sets was guided by the research questions which the study sought to respond to and the three sets of data were collected at four different stages of the research design. These stages of data collection were strategically designed to yield data that would shed light into the research questions. As indicated in Chapter 1, the research questions address three different aspects of the professional development of the OFTS in TSPCK in the particulate nature of matter.

3.6.1 Impact of the intervention on OFTs' CK in the topic of intervention (particulate nature of matter).

In responding to the first research question, (RQ1) data was collected with all fifteen out-of-field teachers as a set of pre- and post-intervention using the CK test of the TSPCK instrument. The TSPCK in the topic of the intervention was measured using specially designed instruments of TSPCK in the particulate nature of matter by Pitjeng (2014) to assess teachers comprehension of the CK concepts.

3.6.2 Data for determining the impact of intervention on the quality of TSPCK in the particulate nature of matter

In responding to the second research question, (RQ2) data was collected with all fifteen out-of-field teachers as a set of pre- and post-intervention using the TSPCK tool in the particulate nature of matter. Both the CK and the TSPCK of the teachers were measured before the intervention. The TSPCK in the topic of the intervention was measured using specially designed instruments of TSPCK in particulate nature of matter by (Pitjeng, 2014) to assess teachers' grasp of PCK components and its interactions in the particulate nature of matter.

3.6.3 Data for determining the impact of the intervention on the quality of eTSPCK in the particulate nature of matter

Videos are advantageous in a study which involves qualitative research approach in that, they provide a researcher with an opportunity to have permanent data which could always be replayed for verification purposes at any time when a researcher needs to double-check some data episodes captured by video recorders. Observations were used to collect data on the classroom practice of the OFTs teachers before and after the intervention programme on the topic of intervention. To respond to the research question (RQ3) on the impact of the intervention on the quality of the enacted PCK of out-of-field teachers, data was collected with only 3 out-of-field teachers as set of pre and post-intervention classroom observation. Two lessons were observed for each teacher. Teachers were followed into their classrooms to capture data on their teaching of the topic of particulate nature of matter. Videos were used to collect data on teachers' TSPCK post the intervention to capture the manner in which the TSPCK develops or translates into classroom practice. Table 3.3 provides a summary of the data collections aspects.

Table 3.3: Data collection aspects

Research Aspect	Activity	Data Collection method in the particulate nature of matter	Number of Participants
1. Impact of the intervention on the quality of planned TSPCK	- Conducting Pre and Post tests	- Pencil and paper TSPCK questionnaires	15
2. Impact of the intervention on the quality of enacted TSPCK in the classroom practice of the OFT	- Conducting pre and post classroom observations - Conducting Interviews	- Video recordings	3
3. Impact of the intervention on OFTs' CK in the topic of intervention (particulate nature of matter).	- Conducting Pre and Post tests	- Pencil and paper TSPCK questionnaires	15

3.7 Data analysis

3.7.1 Scoring and analysing the completed pencil and paper TSPCK tool

For analysis of shifts in the quality of TSPCK in the topic of intervention the completed TSPCK instrument were analysed using a purposefully designed TSPCK rubric adapted from an initial design by Park & Chen (2012). Several studies have used rubrics to score the participant's responses, for example, Mavhunga and Rollnick (2013) and Park, Jang, Chen and Jung (2011). The rubric that was adapted was by Pitjeng (2014) from Mavhunga and Rollnick (2013) (see Appendix 4 for a full copy of the rubric). The rubric has categories corresponding to the five knowledge categories of the TSPCK, with each being rated on a five-point scale, from 0 (No response), 1 (Limited), 2 (Basic), 3 (Proficient) and 4 (Exemplary). A teacher response that demonstrates only standardized textbook definitions to address the component without any evidence of drawing on other TSPCK components was assigned a score of 2, showing 'basic' TSPCK. If a teacher response expanded on the standard textbook definitions, using one more other component interactively such a teacher was awarded a score of 3 for developing TSPCK. In addition, a teacher response which demonstrated evidence of engaging the topic by drawing from two or more components, demonstrated 'exemplary' TSPCK and such a teacher was awarded a score of 4. Figure 3.5 is an extract of category A of the rubric showing the levels of rubric from limited to exemplary.

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

Figure 3.5: A TSPCK rubric extract for scoring component of learner prior knowledge

The generated scores were used to interpret each response that teachers gave on their open-ended written instruments and the extent to which a particular teacher could transform his or her CK through the knowledge components of the TSPCK. Thus, the rubric was used for this study to indicate whether the teacher's understanding of a knowledge category is limited, basic, proficient

or exemplary.

3.7.2 Scoring and analysing the completed pencil and paper CK tool

For analysis of shifts in the CK, the data collected using the CK instrument before and immediately after the intervention were scored using a memorandum of correct answers. The memorandum came from a study by Pitjeng (2014) which was constructed with a reference team of experienced science teachers and thus considered valid. The shifts between the pre versus post scores in the completed CK were analysed quantitatively and qualitatively. The mean of the pre and post was compared for statistical significance difference using statistical models for non-parametric data as the sample is anticipated to be small according to statistical terms.

3.7.3 Using Rasch Statistical Model to determine reliability and validity

Rasch analysis is a quantitative technique that is used for the analysis of categorical data and provides an estimate of reliability and validity. The key aspects of the Rasch model are reports on the two constructs of reliability of the data subjected in the model. Firstly, the model reveals the person separation reliability index estimates of the observed variance and this was the CK and the TSPCK in this study. Secondly, the item separation reliability, which is an indication of the ability to define a distinct hierarchy of items along with the measured variable and the replicability of item placement within the hierarchy across other samples (Boone & Rogan 2005). Additionally, this model reports on the reliability of an instrument by producing internal consistency coefficients like Cronbach's alpha (Tavakol & Dennick, 2011).

The Rasch statistical model entails transforming the raw scores from ordinal data, into statistical measures that are located on a linear scale with equal intervals (Bond & Fox, 2015). The linear scale allows for the determination of an empirical hierarchy with respect to the person's ability to respond and the hierarchy for item difficulty. In this study, the scores generated from memorandum of CK test and rubric for TSPCK in the particulate nature of matter were transformed into numerical clusters which were then subjected into Rasch analysis using *Winisteps package.* In chapter, 6 and 7 of this study the detailed Rasch analysis are given for both CK and TSPCK tools.

3.7.4 Analysing recorded video lessons

An integrated in-depth analysis method was used to recognize the interacting TSPCK components in a specific teaching segment recorded in the video. Park and Chen (2012) argued that the interaction of the components of the PCK was an indication of the effectiveness of PCK and by inference, the TSPCK and this argument also holds for TSPCK. The TSPCK episodes in this study are defined in a similar way to Park and Chen (2012) for the PCK interactions. TSPCK episodes are an indication of moments in a teaching segment where two or more of the TSPCK components were used interactively to explain a specific concept.

The data collected on TSPCK in the topic of intervention during classroom observations using a video camera was analysed for its quality. This was based on the extent to which the components interact in the captured TSPCK episodes and expressed as TSPCK Maps (Park & Chen, 2012). The data collected was organised into chunks of components of knowledge called TSPCK. For analysis of the eTSPCK in recorded video lessons in-depth analysis of TSPCK episodes were conducted. This method required a TSPCK episode to be defined and the components of the TSPCK involved, identified and again represented using an artefact called TSPCK Maps (Park & Chen, 2012). The quality of the identified TSPCK episodes from teachers' lessons was further analysed using a rubric designed and validated in a separate study by Miheso (2018) (see Appendix 5 for a full rubric). In this study, the identified episodes were matched into pre-determined categories of quality of TSPCK rubric for scoring TSPCK in action or eTSPCK level. The rubric has three categories of quality which capture and display the quality of TSPCK as well as a level of complexity. The details of the TSPCK rubric in action are presented in Chapter 7.

3.7.5 For analysing of Interviews and WhatsApp Messages

- **Interviews**

The interviews were transcribed verbatim. As alluded to in section 3.3 interviews were meant to gain further insights into the pedagogical thinking and reasoning of teachers about their CK before and after the intervention. However, the data collected from these sources was not substantive about the construct under study and as a result, they were not included in the data analysis chapters. Table 3.4 is an excerpt of teacher Amanda's reflection after teaching her first two lessons before exposure to the intervention.

Table 3.4: Interview questions with teacher responses

Interview Question	Teacher Response

Question: Kwi lesson yakho [a Xhosa word meaning in your lesson] - what were you trying to achieve, what were you hoping to achieve with learner?	*Ok first of all I wanted my learners to know the three stages of matter, which is the solid, liquid and gaseous stage and I knew that since they are doing Grade 8 they know what is matter, so when you're coming up with the new concepts, you must ask them with the previous knowledge as I did so I knew that they really understand what is it because they said it is everything around us then after I taught them there are three stages of matter. They must really understand and believe that because I believe as a science teacher. If you just theorize over concepts, it does not make much sense to the learners.*
Question: Ok thank you Mem, when you were planning your lessons, what was, as you said you're taught these topics already? What are the lesson difficulties in learning it with the topic? The areas that you think it's difficult for them to understand with the topic, misconception as you saying.	*Teacher: Yes, no it was my first day teaching them the phases of water because it's in term. I've done it for those who are doing Grade 9.* *Question: Okay, no I am asking for those who are doing Grade 9.* *Teacher: These ones it just!* *Question: Ya [informal word meaning Yes] I am asking with the grade 9s, what the difficulties are?* *Teacher: Ok, yes, it's a misconception, it's a misconception for instance they like to misinterpret the evaporation and condensation. They don't really understand some of them, not all of them. Their misconceptions are different because the others they know that evaporates and the process is evaporation but the others they think that it condenses instead of saying evaporation. Another thing I have notice about the learners is that the, the I don't know maybe it's because of me, I don't give them a chance to speak Xhosa because I know once they are always saying things in Xhosa, they won't be able to understand it and it won't be asked by Xhosa so.*

In the interview above, teacher responses do not provide the reasoning behind the lesson, for example, the teacher was asked to reflect on learning difficulties which she thought were inherent in teaching the topic. The teacher mentioned that it was her first-time teaching Grade 8. Thus, these were cut short as they gave no substantive insights into teachers' pedagogical reasoning. Their limited background of chemistry might have caused their inability to reason about their teaching. This was the case with all three teachers.

- **WhatsApp Messages**

As alluded to in the sections above, the WhatsApp platform was meant to further assist teachers to continue developing their PCK of topics beyond the face-to-face intervention.

Teachers were allowed to share any school work they wished to discuss with the group. Similarly, one of the OFTs taught the concept of atoms through a classroom task which instructed learners to draw using orbitals and represent the number of electrons that each element contained. The teacher was then asked to take a few answer sheets of the learners and show how she went about in facilitating learning of atoms through these worksheets. The Figure 3.6 was one of the few learner tasks which a teacher sent to me via e-mail and was discussed via WhatsApp.

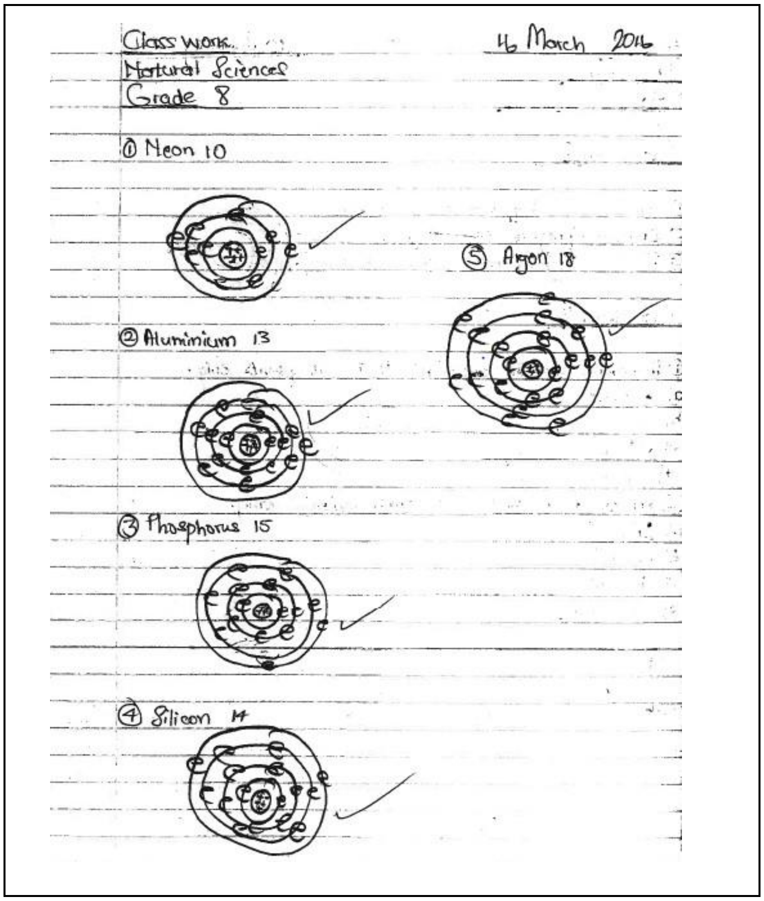


Figure 3.6**:** Teacher's activity sent for Analysis to WhatsApp group

In this activity, it was identified that the teacher herself had misunderstood the concept. It was noted that this platform became more about teachers confirming content difficulties rather than displaying their enacted PCK at Topic-Specific level beyond face-to-face intervention. As a result, the WhatsApp messages also proved to be less substantive in giving insight into teachers' ePCK beyond face-to-face intervention.

3.8 Data Quality

The use of mixed methods research in a study means both quantitative and qualitative research methods were employed. Mixed methods study both validity and reliability (for quantitative data) and trustworthiness of data are important constructs to illustrate how strengths of each of these two methods complement each other or otherwise This calls for triangulation of findings to reduce biases. The validity constructs from each method improve the quality of data and consequently, the overall findings of the study. While mixed methods research employs both quantitative and qualitative research methods, for the validity of the study both these methods must conform to specific validity requirements (Cohen et al., 2011).

3.8.1 Validity and reliability of quantitative data

- **Validity**

In quantitative research, validity is a measure of whether the research measures what it intends to measure. One aspect of this study was covered by the use of different researchers to form a reference team to score the same instruments. The second aspect was the construct validity that took into consideration evidence of statistical inference validity. The scoring of TSPCK questionnaires and video codes were subjected to two raters and their scores compared using the Cohen Kappa index.

- **Reliability**

The reliability of a quantitative study measures the extent of accuracy in the results of the instruments when repetitively administered in similar contexts. The Rasch model achieves this level of accuracy through estimates of internal consistency of the items of the instrument used. The Rasch statistical model was used. The model is built on the idea that the recorded performances are reflections of a single underlying construct, which is made explicit by relationship of items to the human ability in the sample measured (Bond & Fox, 2015). The Rasch model calculates reliability in two ways. It calculates the item as well as the person reliability. Item and person reliability scores are placed on a scale from 0 to 1 score that falls above or equal. The various data sources in this study were used to interpret several occurrences underpinning the phenomenon under study. Equivalence is also a key aspect of the reliability of an instrument measure through inter-rater reliability measures. The responses from TSPCK instruments were scored through a rubric specially designed to score TSPCK instruments. Two researchers further scored these scores independently in order to improve the inter-reliability purposes. The scored TSPCK questionnaires were subjected to two raters and calculated through the Cohen Kappa index.

3.8.2 Trustworthiness of qualitative data

In qualitative research, several constructs such as credibility, dependability, transferability and conformability determine the overall trustworthiness of qualitative data.

- **Credibility**

The key aspect of credibility is the congruency between findings and reality data presented. One of the provisions that one could undertake to promote confidence that the phenomenon under study was recorded accurately is triangulation. Triangulation promotes the use of various data collection methods. This variety of data sources warrants that weaknesses in the findings from one source can be strengthened by findings from another data source, resulting in overall data credibility of findings of the study. In this study, the guiding principles for the credibility of qualitative data were taken into considerations through triangulation. Different methods of data collection were used and such methods included the CK tool, the TSPCK tool and the video-recorded classroom observations. Firstly, in analysing and scoring data from the TSPCK tools, a reference team of three independent raters who were experienced science teachers, and who were also undertaking their studies on TSPCK research was formed. This reference team of co-researchers in the field of TSPCK research scored both the TSPCK tools and the video-recorded lessons independently and eventually met for interrater-reliability agreement purposes. The interrater reliability index was a product of agreement in Individual scores and those of interrater reliability and Cohen’s Kappa method was used to calculate this construct.

- **Dependability**

The dependability of a qualitative study is another important aspect that contributes to trustworthiness. For any qualitative study to be considered dependable, in-depth descriptions of the research processes that were undertaken should be reported in detail such that if repeated in the future similar outcome of the findings might be achieved. These thick descriptions of research processes produce a report that clearly states the methods used and their effectiveness.

In this study, the research design (see chapter 3) of the study and how it was executed is provided in detail (see chapters 4 -7). The operational detail of data gathering as well as critical reflection on the findings (see chapter 8) were provided. The detail in the research processes undertaken allows future researcher a deeper understanding of the research design and its implementations, thus strengthening the dependability of the study. The extent of agreement between the researcher's scores and those awarded by the independent raters were validated using Cohen's Kappa inter-rater reliability calculations for qualitative items (Landis & Koch, 1977).

- **Transferability**

Transferability in qualitative studies refers to the extent to which a particular case study can be applied to a wider population. Yin (2013) refers to this as analytical generalizability. The generalizability of this study was strengthened by the sample of the study which represented any other teacher who might be teaching science (chemistry) out of field of teaching at Junior Secondary level.

- **Confirmability**

Shenton (2004) argues that the important aspect of confirmability as a trustworthiness construct lies on the assurance that the findings of a study are a product of the experiences and ideas of the participants and not characteristics and preferences of the researcher. The triangulation strategy under credibility construct was employed in this study to ensure that biasness as a researcher was reduced. This ensured that the findings and deductions emerged from the data and not from the researcher's ideas.

3.9 Research Ethics

Cohen et al. (2011) argue that in educational research, the protection of participants against violation of their rights to freedom, their self-determination to consider all possible options when participating are key aspects of good ethical conduct in research. It is important that participants make voluntary decisions regarding whether they would like to participate or not as such were ethical issues that need to be taken seriously to protect participants. Ethics also involves informing the participants about the rationale of the study and the procedures which the research would follow, for example, protection of data (see Appendices 19, 20, 21, 22 and 23). An ethics clearance application was submitted to the Humanities Faculty Ethics Committee for approval. Permission was granted to conduct this research study. (See Appendix 1 for the Ethical Clearance Award).

The rights of the participants in this study were protected throughout the study. Prospective participants were informed from the onset that their participation was voluntary (Cohen et al., 2011). In the case of anonymity and confidentiality of learners in video recordings, the video recordings were focused on teachers only. In a case where a learner was captured by video due to uncontrollable context and movements of a teacher through the classroom, all efforts were made to make sure that learners view was blocked out in a video. When something they said had to be quoted then pseudonyms were used to ensure that their names were not mentioned. All stakeholders involved in the research were informed about the proceedings of the research through consent letters. An intensive intervention programme was conducted to introduce Natural Sciences teachers to the construct of TSPCK. The following tools were used to collect data for this study: TSPCK instruments to collect data on science teachers' current understanding of content in this topic of the particulate nature of matter. The intervention took place in the local venue where teachers normally meet for their professional development programmes and their normal timetable of these programs were adhered to. After the intervention out-of-field Natural Sciences teachers were brought together during their normal classroom lessons and the video-recorded camera focused on the teacher and not the students. The data gathered was analysed and written up for a thesis which was submitted to Wits University. The data was also used to develop conference papers, journal articles, conference presentations, and other publications as part of the study but individual privacy was maintained in all published and written data resulting from the study. In an event where there was a need for me to refer to something a teacher said during data collection, I used pseudonyms to protect teachers, schools' names as well as learners.

3.10 Reflexivity on data collection

At the beginning of the study, it was envisaged that data would be collected using TSPCK instruments, interviews, video-recorded lessons and WhatsApp messages. The first data collection methods that were deployed were TSPCK instruments. These were administered on the first and last day of the intervention. However, these instruments were long and took time for teachers to complete. This was the first challenge that did not work well as this process competed with the limited time that could have been used for actual face-to-face activities of the intervention. If these were administered separately from the time allocated for face-face intervention, this could have given more time for unpacking and re-building the transformation components of TSPCK. However, the fact that these instruments were designed and validated by a group of experts worked well because they became the key data source to answer the second research question on impact of the intervention on the quality of TSPCK.

Secondly, the video-recorded lessons worked well for data collection as these captured all classroom moments that would have been missed without these recordings. It was envisaged that at least six teachers would provide a much deeper analysis to answer the research question on the impact of the intervention on the quality of eTSPCK. Thus, the initial subset followed to classroom were six teachers, however three teachers became unavailable for post-intervention classroom observations, for different reasons such as teacher union meetings and family related affairs like funerals. Out-of-field teaching is a worldwide practice, it would have saved time and money if data was collected within the Gauteng province where the researcher was based. It would also mean the researcher could have had enough time to chase teachers and wait for them to return back to classes.

Thirdly, it was envisaged that supplemental data would be collected through interviews and WhatsApp messages to further gain insights about teachers' TSPCK and eTSPCK before and after the intervention. However, these did not work well because they deviated from the purpose of the study.

3.11 Conclusion

The purpose of this study was to improve the CK, the TSPCK and the eTSPCK in of out-of-field science teachers who were teaching natural sciences in the rural Eastern Cape. In this study. The OFTs were exposed to an intervention that had its signature on an explicit focus of the TSPCK in the particulate nature of matter. Due to the tacit nature of PCK, various research methods were used to conduct this investigation. The research design used was Mixed Methods using the case study approach. The insights into the impact of the intervention on improving teacher's CK, TSPCK and eTSPCK were gained through quantitative analysis of the CK and TSPCK tools followed by qualitative analysis.

Firstly, a cohort of fifteen teachers completed the TSPCK instrument and their responses were scored using a memorandum and a designed rubric. The scores generated were then subjected to Rasch analysis. The Rasch analysis provided insights into the CK and the quality of the TSPCK of the teachers before and after explicit exposure to the intervention.

Secondly, a sub-set of three teachers were then followed into their classrooms for lesson observations to gain insights into the quality of their eTSPCK as a result of exposure to the intervention. The video-recorded classroom lessons were analysed using in-depth qualitative analysis to gain insight into the quality of their eTSPCK before and after the intervention. Additional data such as interviews and WhatsApp messages were part of data collection methods used to further gain insights about teachers' TSPCK and eTSPCK pre- and post the intervention. These were transcribed and an attempt to analyse them were made, however, these were not informative as these deviated from the purpose of the study. As a result, these data sources were not mentioned hereafter. The choice of research design and methodology of this study including the data collection methods, sample and data analysis techniques ensured high-quality data for this study. The ethical consideration measures were set to ensure the protection of all participants. The detailed analysis and findings of the study are presented in the chapters that follow.

CHAPTER 4

PROFESSIONAL DEVELOPMENT INTERVENTION

In general, practicing teachers develop their on-going teacher professional development from reflections of their practice often in their field of specialization and a fortunate few, through exposure to on-going structured professional development programmes. However, the out-of-field teachers (OFTs) lack both the specialization and a repertoire of experience in the field to draw from; thus, the need for professional development programmes to support them. In this chapter, the features mentioned in the Literature Review as essential for a professional development programme and how they were incorporated into the intervention in this study are recapitulated. The design of the intervention and how the OFTs were engaged to develop their competence to pedagogically transform content knowledge through the TSPCK components are described. Finally, the value of Content Representations (CoRes) as a planning and developmental tool is examined.

4.1. The principles behind the design of the intervention

The specific type of professional development adopted in this study was Continuing Professional Development (CPD). CPD is perceived as a programme that focuses on a set of knowledge and skill-building activities which enhances teachers' ability to respond to classroom challenges more efficiently. In the literature review in Chapter 2, five methodological core features are highlighted which produce continuity and sustainability in an effective CPD. The design of the intervention relies on two major principles.

The first principle acknowledges methodological elements (the "how to run it"), and this principle adopts continuity and sustainability as advocated by Main and Pendergast (2015). The authors advocate that continuity and sustainability are important elements for CPD, and should be incorporated in all effective CPD programmes. Furthermore, Main and Pendergast (2015) point to five core features that ensure continuity and sustainability. These are (i) target content knowledge development; (ii) collective participatory orientated as opposed to lecture-based, (iii) active learning, (iv) coherence (which implies practice-based) and (v) duration, which means adequate time as opposed to once-off injection CPD. These features were adopted and recognized as important for inclusion in the structure and approaches used in the teacher professional development intervention designed for this study.

The second principle was on knowledge for fast-tracking the development of professional knowledge for teaching science. Thus, the second principle acknowledges the professional knowledge needed to teach a specific topic. This principle adopted the inclusion of TSPCK. Main and Pendergast (2015) argue that CPD is important for teachers to enhance their pedagogical content knowledge (PCK) and skills for effective teaching. Shulman (1986) indicates that subject matter knowledge alone cannot translate into effective science teaching. This implies that while a focus on the content knowledge (CK) is essential in CPD, it is however insufficient for developing teachers' competence for teaching effectively. Anderson and Clark (2012) echoed similar sentiments and argued that teachers need to know not only content knowledge but also knowledge of how to transform content knowledge into teachable forms which is Pedagogical Content Knowledge (PCK). The science education community in general, regards PCK as the special knowledge teachers need to teach science. For development of teachers the level of PCK needed is topic specific, called Topic Specific PCK (TSPCK) (Mavhunga & Rollnick, 2013).

Central to the construct of TSPCK is the understanding of the five knowledge components and the skill to use them interactively to formulate explanations and answer questions. The understanding of the topic from the perspective of the knowledge derived from the TSPCK components brings about the desired transformation of the CK into versions accessible by learners (Mavhunga & Rollnick, 2013). The exposure to pedagogical transformation further exposes participants to ways of reasoning their CK for their learners' understanding, the overall goal of PCK.

The design of the intervention in this study thus brought together both the important features related to the running of an effective CPD and the knowledge for the professional development of teachers – TSPCK in the particulate nature of matter. The particulate nature of matter was used as a topic of intervention because it is regarded as difficult to learn due to its abstract nature (Andersson, 1990). Furthermore, the topic forms the basis for the understanding of several topics in chemistry and is thus considered as a fundamental concept in chemistry as a discipline (Gabel, Samuel, & Hunn, 1987). The structure and the content of the intervention are discussed in detail below.

4.1.1 The structure

The principle of 'continuity and sustainability' was encapsulated in the structure of the intervention. The intervention comprised of face to face sessions that spread over 5 days. The researcher facilitated the 5 Day training during the intervention. Fifteen OFTs were exposed to 5 x 5 hour-long sessions unpacking the construct of TSPCK and re-building it for learning to teach the topic – the particulate nature of matter. This was to ensure the OFTs had sufficient time to engage with the construct of the TSPCK components to learn to teach the particulate nature of matter. The focus in this phase was to explicitly assist the OFTs to develop teacher knowledge to transform CK through the interactive use of the components of the construct the TSPCK.

The TSPCK-orientated activities designed for these sessions were structured in a way that promoted the development of both content knowledge in amalgamation and pedagogical knowledge. Furthermore, these sessions were structured such that they allowed the OFTs an opportunity to learn the skill of interactively using the TSPCK components in formulating rich explanations for learner understanding. The activities used during this phase were teacher-orientated tasks which posed real classroom scenarios where a teacher would need to respond to a specific learner misconception. These kinds of activities were meant for the OFTs to relate what was learnt in the intervention with their classroom contexts. The teacher-orientated tasks used during this CPD were designed based on the curriculum that learners were expected to know at Junior Secondary level. This implies that the structure of this intervention was coherent to OFTs' real classroom practice, and this is the *coherence* adopted as crucial in designing effective TPDP.

The 5 days were found to be adequate to introduce the OFTs to a framework that could assist them to pedagogically transform their CK through the interactive use of the TSPCK components. The *duration* of CPD was adopted and recognized as a crucial feature in designing an effective CPD (Supovitz & Turner, 2000). During the school visits of the selected three OFTs, these teachers discussed their lesson plans before going to the classroom. After each lesson, teachers met with the researcher to reflect on how their planned lessons turned out in practice. 'During these reflection sessions, the researcher further assisted the OFTs in developing their competence to pedagogically transform the CK through the interactive use of components of the TSPCK. All together the intervention happened over 4 weeks. Figure 4.1 illustrates the integrative nature of the structure of the intervention.

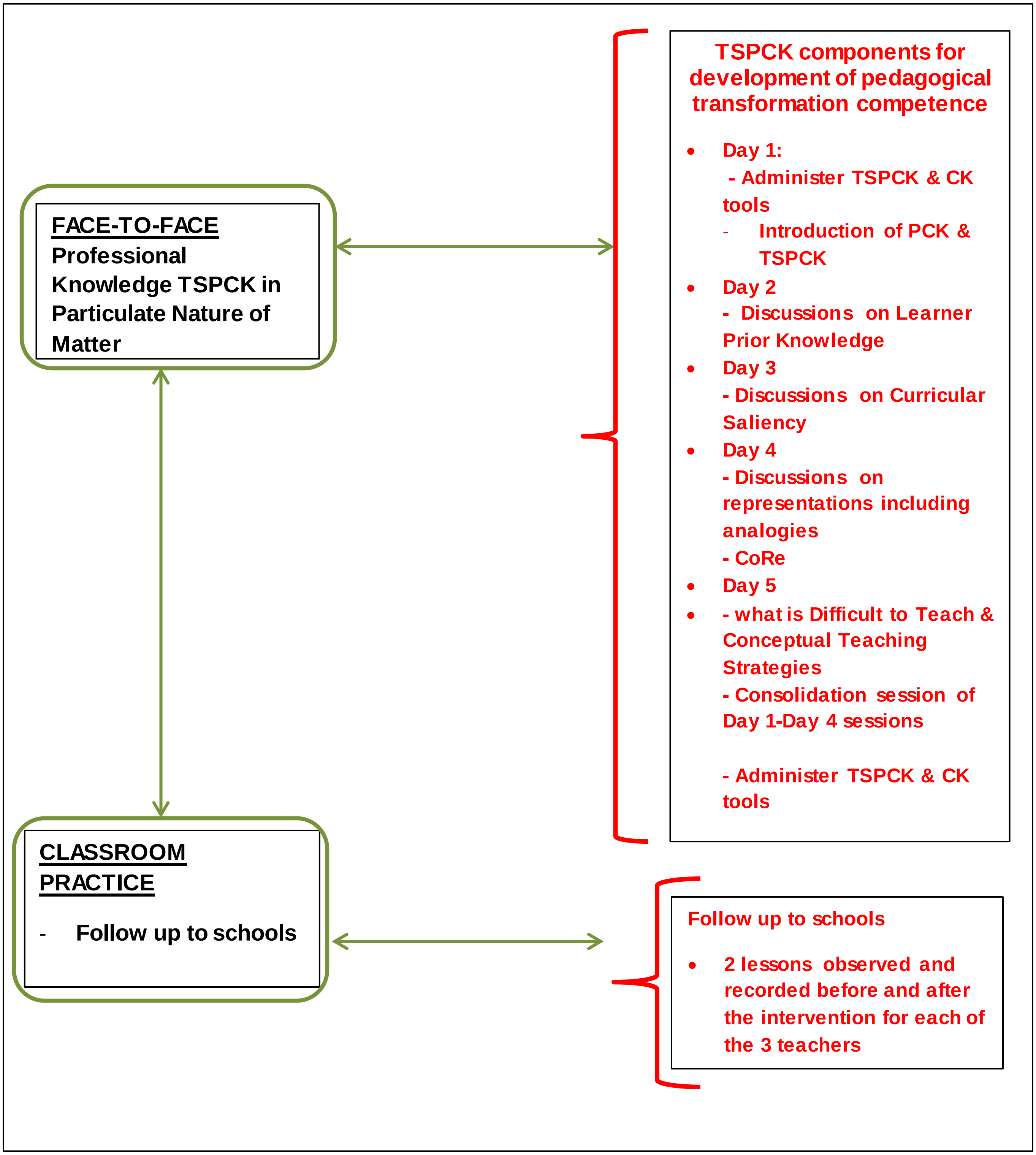


Figure 4.1: Integration of the core principles for the structure of the intervention

The diagram and discussion above show how features of effective CPD were incorporated in formulating the structure of the intervention designed for this study. The above-mentioned features were adopted and recognized as key.

4.1.2 The content of the intervention

One of the anchoring principles which structured this intervention was the incorporation of the Topic-Specific knowledge for teaching science of the particulate nature of matter. The development of the TSPCK in a specific topic can be achieved by explicitly exposing teachers to five knowledge components of the TSPCK which facilitates the transformation of the CK. Previous studies have argued that important key features were in:

(i) learning knowledge of TSPCK components which TSPCK emerges from the perspective of the topic and

(ii) learning the skill of using the components interactively to formulate teacher responses and explanations (Mavhunga, 2016).

Thus, the intervention was set up in a way that the TSPCK components that bring knowledge for transformation of the CK were introduced and explicitly explained one by one. The explanations of each the TSPCK components were accompanied by illustrations showing how each component was applied interactively in teaching the particulate nature of matter. The nature of the TSPCK construct is such that while the TSPCK components were introduced one at a time, the other components emerge spontaneously in the explanations.

During workshops and classroom teaching where one component was introduced but other components were emerging, such moments were highlighted and pointed out to the OFTs. For example, during the face-to-face, in a case where the emerging component/s was to be discussed in the upcoming sessions, the OFTs were asked to make a note. The explicit pointing out of cases of component interaction was to encourage the OFTs to take note of the way the TSPCK components interact.

Collective participation and *active learning* are recognized as key features for effective CPD. Thus, the intervention was designed in a way that fostered collective participation through the teacher-based tasks that required the OFTs to engage in participatory orientated CPD rather than lecture-based setup During the face-to-face phase, the OFTs were divided into groups of four with each group presented by four teachers, while one group had three teachers, to make the total of fifteen. Teachers were expected to keep their groups for the rest of the week. Each group was expected to develop a CoRe collaboratively towards the end of the intervention on day 4 to assess their knowledge acquisition towards opportunities. This task allowed the OFTs opportunities for active learning and collective participation.

Out-of-field teaching is understood as a teaching practice where teachers are teaching content areas outside their field of expertise. It, therefore, makes sense that any CPD that ought to bring knowledge. pedagogical change to this kind of practice should include addressing content.

On the other hand, it is been previously argued that for content covered during the CPD to be effective in teachers' real classroom practice it should be coherent with teachers' real classroom practice Kenny, Hobbs, and Whannell (2019). It was therefore very important for this intervention to make sure that activities and tasks given to teachers are practice-based for it to yield the coherence adopted as the core for the structure and content of this intervention. For example, the incorporation of TSPCK in the content of this intervention included concepts of the particulate nature of matter and therefore content knowledge was brought through explanations of TSPCK components. The CK incorporated in both the TSPCK components and the CoRes were aligned to the CK that learners at Junior Secondary level were expected to learn

The discussion above provides an overall picture of how the two major principles of this intervention were incorporated for the implementation stage. The detailed discussion of how features that informed structure were incorporated on the content of the intervention is provided below.

4.2 Implementation of the face-to-face Intervention

As alluded to in Chapter 3, the approach for the intervention follows that of signature interventions carried out through science education methodology courses in one of the best universities in the country. The pre-service science teachers' programme at the university implements the TSPCK in two stages of their BEd programme. Firstly, in the 1^{st} and 2^{nd} year of the programme for Natural Sciences and secondly at the 3^{rd} and 4^{th} year focusing on Life sciences or Physical Sciences. According to Mavhunga and Rollnick (2017), the content knowledge of pre-service teachers at this stage is inherently poor from their school backgrounds thus in the first two years, explicit discussions on the TSPCK focus only on three of the components. The three content-specific components, namely, learner prior knowledge, curricular saliency and representations results in the guaranteed exposure to TSPCK.

Similarly, poor content knowledge was one of the key characteristics of OOF as alluded in literature review in chapter 2. It then became a challenge to implement the PCK at a Topic-Specific level with these teachers and as a result, there were fewer interactions than expected, at the beginning of the intervention. However, as the intervention progressed these teachers were allowed to reflect their acquired knowledge using CoRes to make the intervention a combination of lecture-based approach and collaborative participation. This combination allowed teachers to practice and portray their acquired understanding at different stages of the intervention while getting valuable feedback from the collective. While in this study teachers were exposed to all content-specific components. More focus was directed on the three selected components similar to the first stage of BEd implementation above.

The purpose of this intervention at this stage was to introduce teachers to PCK and discuss in detail the TSPCK content-specific components from which the transformation of content knowledge emerged. The intervention strategically took place in the first week of the second term of the school calendar so the OFTs were expected to return to schools after the vacation to cover the subject of the particulate nature of matter. The particulate nature of matter is largely introduced at Junior Secondary level and it is a major concept at that level because it forms bases of their chemistry journey through high school.

4.2.1. Series of TSPCK signature workshops for out-of-field teachers

As alluded to in the discussions above, during workshops all five components of the TSPCK were introduced. However, more emphasis was put on the three selected components of the TSPCK. It was explained to teachers that the broader PCK was different from the TSPCK and when planning and teaching are concerned, the content is approached per topic. TSPCK and the topic of the intervention, which was the particulate nature of matter, was used to illustrate the application of the TSPCK for content transformation purposes. Table 4.1 shows a summary that describes the TSPCK components and their corresponding discussions on each day of the intervention together with specific concepts used in the particulate nature of matter.

Table 4.1: The sequence of the activities of the intervention

Day	Hours	TSPCK component used	Intervention activity	Concepts of CK used
1	5	Overall introduction of PCK and TSPCK and components of TSPCK	Administer TSPCK instruments.	- Overall introduction of TSPCK and its components
2	5	Learner Prior Knowledge	• Discuss and revision on learning and teaching of Particle Nature of Matter. Introduce the 1st component of learner misconceptions with respect to TSPCK construct as a whole.	- Particle behavior during phase change - Microscopic representations of different types of particles in different phases - Particle nature of matter at gaseous phase (expansion, contraction, pressure, arrangement of gas particles) - Use of different representations to emphasise different concepts of particle nature of matter
3	5	Curricular Saliency	Introducing Curricular Saliency	Big ideas: - Particles are in constant motion - Matter is made up of small bits that are called particles - Matter is made up of small bits that are called particles - There is empty space between particles - There are different types of small bits of substance with different arrangements - Particles of different substances are different with different
4	5	Representations	• Introducing Conceptual Representations & Teaching strategies. Wrapping up the workshops. • Tabulating teacher understanding on learner misconceptions, Curricular Saliency and Representations through designed prompting questions (CoRes)	- Identification of both micro and macroscopic representations of particle nature of matter - Microscopic representations of different types of particles in different phases

5	5	Teaching strategies & What is difficult to teach Consolidation session	Administer TSPCK instruments Complete the CoRe	- Pulling everything together through CoRe and consolidating all the extracts from bits of CoRe used in each session. - Incorporation of curricular saliency, what is difficult to understand and conceptual representations in formulating conceptual teaching strategies to deal with the misconceptions - Highlighting the manner in which misconceptions can be used to think about appropriate conceptual teaching strategies to deal with the above-mentioned misconceptions. - Administer TSPCK tools

4.3 Signature Assessment Vignettes during the intervention

As discussed in chapter 3, the science education methodology courses which this intervention was adapted from carries out both formative and summative assessments (TSPCK tools and/or adapted CoRes). The reason for these assessments is to get deeper insights of acquired specialised knowledge for teaching science topics and the interactive use of the PCK in transforming content. As indicated above, the TSPCK tools were used to assess the TSPCK of teachers before and after the intervention. The detailed analysis and findings of the TSPCK tools will be reported in chapters 5 and 6. In this section, only a summary of insights from the adapted CoRe is presented. Figure 4.2 is the adapted CoRe.

Curricular saliency	What do you intend the learners to know about this idea? *(original CoRe item – geared to capture subordinate concepts)*
	Why is it important for learners to know this big idea? *(original CoRe item – a potential window to observe any consideration of the other TSPCK components in the provided reasons)*
	What concepts need to be taught before teaching this big idea? *(original CoRe item – captures pre-concepts)*
	What else do you know about this idea (that you do not intend learners to know yet)? *(original CoRE item – captures what is considered peripheral)*
What is difficult to understand	What do you consider easy or difficult in teaching this big idea? Explain. *(new question added)*
Learner Prior Knowledge	What are the typical learners' misconceptions on this big idea? *(new question added)*
Representations	What representations will you use in your teaching? *(new question added)*
Conceptual teaching strategies	What conceptual strategies would you use in teaching this big idea? *(new question added)* What questions would you consider important to ask in your teaching strategy? (*adapted from original: captures teaching procedures)*
Reflections	What ways would you ascertain students' understanding *(adapted from original: captures specific ways to ascertain students' understanding*)
	What aspects of planning and teaching this big idea would you like to reflect on *(original CoRe item)?*

Figure 4. 2: Adapted CoRe

Similarly, in this study the adapted CoRe by Mavhunga and Rollnick, (2017) was used based on the formative assessment principles, meaning that these were used in the intervention for developmental purposes. As a result, the teacher responses from these tools only gave insights into the knowledge development of teachers as intervention progressed. Additionally, the TSPCK rubric was used informally and very superficially to get hints of how teachers were progressing towards developing their TSPCK. The final product of their knowledge acquisition after the intervention was assessed using the TSPCK tools that were discussed in Chapter 3. The adapted CoRe was used to reflect explicit prompts on the five components of the TSPCK. To ensure active learning of the OFTs and collective participation, the teachers were introduced to a concept of content representations (CoRe) on the fourth day of the intervention. It was explained to the OFTs that CoRe is a tool that they could use in portraying their reasoning of content knowledge through five TSPCK components. The OFTs were provided with a document and instructed to choose one big idea at a time to complete the document from those that were explained to them on the third day of the intervention.

As indicated in Table 4.1, under the knowledge component of *Learner Prior Knowledge*, aspects and challenges related to the teaching and learning of the particulate nature of matter as well as common learner misconceptions that learners have on this topic were explained to the teachers. Throughout the intervention, in a case where content issues arose, discussions were opened to the whole group before a correct explanation was provided. In that session, aspects and challenges that were related to learning and teaching of the particulate nature of matter were brought to the table and unpacked. How these CoRes were used in this intervention was such that teachers were able to apply them to transform concepts that they were teaching at Junior Secondary level. It should also be noted that it was 'big ideas' of the topic that were explained to teachers and the subordinate ideas associated with these came naturally from teachers when transformed through the TSPCK components.

- **Reflection of LP**

The important aspects of the adopted CoRe on Learner Prior Knowledge (LP) make teachers' aware of their Topic-Specific professional knowledge as well as their learner prior knowledge including misconceptions. Several different concepts in the particulate nature of matter which were considered challenging came up from teachers through CoRes. In this chapter, while four groups developed CoRes, three CoRes were referenced as examples of how these tools were used to assess the acquired knowledge to transform content knowledge. The criteria were that, the extracts from various CoRes that were developed, those that were found helpful to make a particular point in the thesis were used. The rest of the CoRes developed by teachers are given in the list of Appendices as Appendix 8, 9 and 10.

When Group 1 (see Appendix 7) was asked of the typical student misconceptions of the big idea that *particles are in constant motion*, they responded in their CoRe that, *"they [students] do not see the movement of particles in solids, only in liquids and gases".* Group 2 (see Appendix 8 for Group 2 CoRe) chose the same idea. This group of teachers collaboratively came to the consensus that typical misconceptions associated with this big idea included students thinking that

(i) "solid particles do not move

(ii) particles melt in the case of change of state and

(iii) particles will only move when heat is applied".

In this statement, both groups of teachers could identify and acknowledge learner misconceptions associated with the big ideas of their choice. These teachers were in a way unpacking their 'Big Ideas' into respective subordinate ideas from which possibly learner misconceptions emerge. According to the TSPCK rubric designed by Mavhunga and Rollnick (2013) identification and acknowledgement of learners' misconceptions in a specific topic form bases of the quality of the TSPCK from basic to exemplary (see Appendix 4). As a result, the lowest level of the TSPCK quality categories in the rubric means the teacher does not identify or acknowledge the learner misconceptions. It depended on the explanations that teachers gave in addressing these misconceptions whether the quality of their TSPCK remained basic or moved up to the higher categories such as Developing or Exemplary TSPCK.

In teachers' collaborative thinking, teachers reflected their understanding of reasoning of content knowledge through learner misconceptions and transforming the CK through the TSPCK. This was the beginning of how teachers learnt to integrate the knowledge components of the TSPCK to transform, think and reason about content knowledge that they were expected to teach. The teachers' response in this CoRe was evidence that teachers were beginning to reason their content knowledge through the knowledge component of *Learner Prior Knowledge*.

- **Reflection of CS**

Teachers were given prompts to portray their understanding of the TSPCK knowledge component "curricular saliency" (CS). Firstly, the prompts of the CoRe asked teachers what they intended learners to know about the big idea**.** Teachers in Group 1 stated "*that even in solids the particles are moving this is because they are closely packed together. This arrangement will change when the speed [kinetic energy] is changing i.e. when heat is added"*. In these teachers' responses provided, teachers seem to have been able to portray two aspects of the transformation process. Firstly, the teachers were able to give subordinate ideas which are related to the 'big idea' they have chosen namely:

(i) in solids particles are closely packed

(ii) particles in solids were not moving around but vibrate against each other and

(iii) effect of temperature on particles.

The 'big idea' chosen by this group of teachers does not only cover particle behavior at the solid phase but particle arrangement across phases. Teachers gave insights into how they would explain and expand on misconception previously identified in the Learner Prior Knowledge. Teachers were expanding their explanations beyond standardized definitions of the textbook using correct concepts covered in the big idea of their choice. The expansion of concepts beyond standardized textbook knowledge would have put such teachers on the higher-order categories such as developing the TSPCK according to the rubric for measuring the TSPCK.

This is evidence that the tool used to scaffold development of teachers' TSPCK such as the CoRe can be used to promote and guide systematic development that teachers need to reason their CK through the knowledge components of the TSPCK. For example, one of the expected standards for developing the quality of the TSPCK in the component of LP requires teachers to:

(i) identify misconception or prior knowledge

(ii) provide standardised knowledge as a definition

(iii) expand, and rephrase explanation using one other component of the TSPCK interactively.

The teacher response given above in the CoRe has extracts of the standards defining developing the TSPCK category according to the rubric. Furthermore, teachers related the importance of learners knowing this big idea with the notion that *"learners will be able to interpret the causes [the particulate model of matter] and relate them on their daily living*". In these teachers' responses, teachers are giving reasons for the importance of the topic of conceptual scaffolding with the real-life world. Group 3 reflected on their CoRe that the importance of this big idea was related to the fact that "…...*they can be able to compare and differentiate these [atoms, molecules elements] particles".*

In the teacher responses above, teachers gave reasons for the importance of the topic. The reasons given included importance of the topic of the particulate nature of matter for conceptual scaffolding purposes. In addition, teachers drew from their knowledge of LP which they reflected on when prompts were given under LP. This level of reasoning also informs one of the expected standards towards developing higher quality categories of the TSPCK according to the TSPCK rubric. These moments also promoted knowledge of interactive use of components in practice showing that the use of these components was not linear and orderly as they were presented in the workshops. Such cases were always highlighted to teachers whenever they emerged. In their explanations, teachers gave valuable information of insights about their knowledge development of this component in terms of the importance of learners knowing this big idea.

When teachers were also asked concepts that needed to be taught before teaching this big idea, in the CoRe developed by teachers in Group 1, teachers stated, "*the learners should know the particle arrangement* and *size [of particles] remain (does not change), in all these phases of matter".* Finally, teachers were asked what else they knew about the big idea (that they do not intend learners to know yet)", teachers responded that "*use of relevant examples in their environment". Teachers struggled to understand the pre-concepts related to the topic.* Hobbs and Torner (2019) argue that subject specialised teachers understand how sequential curriculum (content structure, big ideas and relationship between ideas) impose certain demands on students to fill gaps in knowledge. This could be a challenge for the out-of-field teachers *as it was the case with teachers in this study*. Such cases gave an opportunity to further re-visit aspects of the TSPCK components where teachers were still showing low levels of understanding during the consolidation on the following day of the intervention. However, these were also showing that the development of TSPCK was not a linear process of development guaranteed to develop immediately after exposure (Mavhunga 2016).

- **Reflection of RP**

Teachers are expected to know conceptual representations (RP) in key concepts to represent content and support student learning (Hobbs & Torner, 2019). As alluded to in the sections above that representation were one of the three components that were the focus of the intervention. In this knowledge component, teachers were asked the representation they would use in their teaching. At this point in the intervention, teachers also reflected superficial knowledge of representations that they would use in teaching their big ideas. For example, Group 1 teachers reflected in their CoRe that they would use "*posters, teaching aids and drawings".* All teachers had these kinds of responses. While these kinds of responses were not incorrect they did not explain what concepts of the big idea would be explained with these posters and teaching aids. These were further explained to teachers through a workshop on the following day.

- **Reflections on teaching strategies**

Teachers were asked to give effective strategies that they would use to teach the big ideas of their choice. Group 2 indicated that they would use practical demonstrations, videos and representations. The teachers added on their CoRe that the question they would consider important to ask in their teaching strategies were *"prior knowledge, interest arousing questions, reasoning challenging questions and knowledge display*" The knowledge acquisition of teachers of teaching strategies was implicit. Teachers in this CoRe presented knowledge of representations and learner prior knowledge as knowledge components that they would incorporate in their teaching strategy. However, in the overarching big idea it was not clear what concepts they would be teaching. Key to the construct of the PCK is the transformation of content knowledge. Thus, in a case where there are no specific concepts addressed through these knowledge components it becomes difficult to analyse such case for explicit TSPCK development.

4.4 Follow up to classroom practice

As mentioned in the previous discussions above, this study acknowledges that the translation of personal PCK into practice develops with time through constant engagements and discussions to remind teachers about the TSPCK components. Instead of assuming that the OFTs would automatically translate what they learnt through the intervention, the OFTs were further followed for classroom observations. The intervention targeted at continuing the explicit discussions that facilitate the development of the OFTs' knowledge to pedagogically transform their CK through the interactive use of TSPCK. In the face-to-face intervention, the learning of this knowledge was developed in the 'planning to teach context' that was observed and assessed in a real classroom. The emphasis of discussions during the intervention targeted at developing teachers' knowledge of the TSPCK components through their application in both the 'planning to teach context' and real classroom practice. Most importantly, discussions were facilitated around the notion of using the TSPCK knowledge components interactively to formulate explanations and demonstrations for learners' understanding. A subset of three teachers were followed to observe their classroom practice. During school visits, teachers were requested to prepare lessons which were discussed before teaching. During lessons, content knowledge misunderstandings from each OFT was picked up and discussed with them immediately. The OFTs went to their classrooms and were video recorded and notes were taken to formulate thick descriptions for areas that a teacher could do more to improve the teaching of a certain topic. The detailed analysis of the enacted TSPCK is presented in Chapter 7, focusing specifically on these three teachers.

4.5. Conclusion

The purpose of this chapter was to report on the signature intervention that had its focus on PCK and premised specifically at the Topic-Specific level. The intervention was aimed at exposing teachers explicitly to the five knowledge components of the TSPCK from which teachers could transform their content knowledge into chunks of information that students can easily understand with emphasis on the content related components of TSPCK. The acquired knowledge of teachers was assessed through the TSPCK tools to get into insights about the improvement of the CK, and the TSPCK before and after the intervention.

In this chapter, there were two principles behind the design of the intervention and these were: structural principles and content principles. The structure of the intervention was informed by five core features that ensure continuity and sustainability as proposed by Main and Pendergast (2015). The content of the signature intervention was heavily premised on the PCK and the TSPCK specifically the five knowledge components which transform content knowledge into teachable form (Mavhunga & Rollnick, 2013).

The implementation of the intervention followed a similar approach to that of the signature interventions described by Mavhunga and Rollnick (2017). CoRes were used from a formative assessment perspective to get insights into the impact of the intervention on improving teacher’s CK, pPCK as the intervention progressed. Thus, CoRes in this chapter were rather used for development purposes but the TSPCK tools were formal tools to measure the TSPCK of teachers before and after the intervention. A sub-set of three teachers were then followed into their classrooms for lesson observations to gain insights into the quality of their ePCK at the Topic-Specific level as a result of exposure to the intervention. The detailed analysis on the impact of the intervention on the their CK, pPCK and ePCK are presented in chapters 5, 6 and 7.

CHAPTER 5

IMPACT OF AN EXPLICIT INTERVENTION ON THE QUALITY OF TSPCK IN THE PARTICULATE NATURE OF MATTER.

Like PCK, Topic Specific Pedagogical Content Knowledge (TSPCK) is a difficult construct to measure based only on one method. In this study, the quality of the TSPCK of teachers, teaching Natural Sciences out of the field of their expertise, referred to as OFT, is measured in both planning and in an enacted context. In this chapter, the analysis of data collected as a set of pre-and post-intervention tests, which measure personal PCK at the *topic-specific level is presented.*

5. 1. Introduction

The OFTs were exposed to a professional development programme that comprised of a structured face-to-face intervention and semi-structured support in schools. This chapter explores possible shifts in the quality of the TSPCK experienced as a result of the face-to-face intervention. The face-to-face intervention happened over five successive full days of training. The data analyzed in this chapter comprises the TSPCK tools on the topic of particulate nature of matter. As mentioned in chapter 3, the tools were completed as a set of pre- and post-intervention tests. The completed tools reflected the personal PCK of teachers at the Topic-Specific level as they were written responses from the teachers (Carlson & Daehler, 2019). Teachers group discussions submitted during the course of the intervention were also collected. As alluded to in Chapter 3, the research method applied in this study was a mixed method. The teachers' written responses from the TSPCK tool were converted into numerical clusters through a rubric to generate quantitative scores. The numerical scores from teacher responses were further subjected to a Rasch statistical model for quantitative analysis to confirm the patterns emerging from qualitative analysis. The teacher responses were also analysed qualitatively through item analysis for shifts in the quality of pPCK in the particulate nature of matter before and after exposure to the signature intervention (see chapter 4).

Like in the case of PCK, TSPCK is a tacit construct and thus the insights of any TSPCK study are best discovered through a combination of quantitative and qualitative methods.

The data collected and analyzed in this chapter seeks to respond to the first research question: *what impact does the intervention have on the quality of OFTs' TSPCK in the topic of the particulate nature of matter?* In responding to this research question, data comprised of the completed TSPCK pre and post tools analyzed qualitatively to establish trends in the quality of TSPCK using a criterion-based rubric is presented. The same data was also analysed quantitatively to measure the extent of the observed shifts or trends.

5.2 Analysis of qualitative shifts in the quality of TSPCK

To analyze the completed TSPCK tools, a validated TSPCK rubric was used to score the responses (Mavhunga & Rollnick, 2013). The rubric has been used in several separate studies (Vokwana, 2013; Pitjeng-Mosabala & Rollnick, 2018). The rubric is criterion-based, and made up of four categories of increasing quality of TSPCK from the lowest category called 'Limited' to the highest, called 'Exemplary'. One of the criteria in each category is the extent at which a TSPCK component would interact with others as highlighted in Figure 5.1.

	(1)Limited	(2) Basic	(3) Developing	(4)Exemplary
Learner Prior Knowledge	• No identification/No acknowledgement/No consideration of student prior knowledge or misconceptions • No attempt to address the misconception.	• Identifies misconception or prior knowledge • Provides standardized definition as a means to counteract the misconception • No evidence of drawing on other TSPCK components.	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Expands and re-phrase explanation using one other component of TSPCK interactively.	• Identifies misconception or prior knowledge • Provides standardized knowledge as definition • Expands and re-phrases explanation correctly • Confronts misconceptions/confirms accurate understanding drawing on two or more other component of TSPCK interactively.
Curriculum Saliency	• Identified concepts are a mix of Big Ideas and subordinate ideas • Identified pre-concepts are far from topic • Sequencing no value due to mixed concepts • Reasons given are generic - benefit of education.	• Identifies at least 3 Big Ideas • Not all 3 Big ideas subordinate concepts identified • Suggested sequencing has one or two illogical placing of Big Ideas. • Identified pre-concepts are far from the current topic • Reasons exclude conceptual considerations and show no evidence of drawing on other TSPCK components.	• Identifies at least 3 Big Ideas • Subordinate concepts correctly identified for all Big Ideas • Provides logical sequence • Identifies pre-concepts relevant to the topic • Reasons given for importance of topic include reference to conceptual scaffolding/sequential development draw on one other TSPCK components e.g. what makes topic difficult.	• Identifies at least 3 Big Ideas • Subordinate concepts correctly identified for all Big Ideas with explanatory notes • Provides logical sequence of all three Big Ideas and with logical reasons • Identifies pre-concepts relevant to the current topic and explanatory notes given • Reasons include conceptual scaffolding with reference to other TSPCK components

Figure 5.1: An extract of the TSPCK rubric for learner prior knowledge and curricular saliency components

Figure 5.1 above is an extract from the TSPCK rubric (see Appendix 4) showing the criteria for the components of Learner Prior Knowledge and Curricular Saliency across the four categories of the rubric. As highlighted in Figure 5.1 above, a teacher response which was scored a numeral 1 and 2 respectively meant Limited or basic category of the TSPCK. This implied that the written response would have fewer interactions of the TSPCK components than responses scoring higher in the Developing and Exemplary categories of the TSPCK rubric which scored 3 and 4 respectively. One of the central aspects of this analysis through the rubric was the extent to which teacher responses engaged interactively with the components of the TSPCK. For example, if a teachers' response in any of the five knowledge components of the TSPCK shows little or no evidence of understanding of a particular component, such response was scored 1, which means Limited TSPCK.

The average scores of the numerical values were used as a proxy to the overall influence of all the component interactions seen in each of the TSPCK components for an individual teacher. The average scores calculated for each teacher were not mere mathematical calculations of average for the knowledge of each component, but rather a reflection of several component interactions seen one at a time from each of the TSPCK components. The TSPCK scores generated from the rubric were then peer-validated between two independent raters and the author. The two raters were chosen based on their familiarity and experience in working with the construct of TSPCK. The process required peer validators and the author to score the completed instruments individually and thereafter scores were shared for discussion and comparison. The inter-rater reliability was established by giving the two independent raters and myself three unmarked copies of the completed questionnaires to score according to the rubric discussed in Figure 5.1 above. The questionnaires were chosen based on the spread of the cohort from poor to good. The raters were given six TSPCK tests in total, a set of pre- and post- tests for each teacher.

One of the ways to establish inter-rater reliability between three independent raters is to combine the raters into three possible pairs (Pieper, Jacobs, Weikert, Fishta & Wegewitz, 2017). One can then add the extent of agreement for each question as seen in the last column then divide the sum by the total number of questions then multiply by 100 to get the mean percentage across the total number of 15 questions for the completed TSPCK instruments. The total mean of 86.6 % was achieved as an agreement between raters for the TSPCK tests. In a case where there was disagreement, all raters including the researcher discussed the differing scores using the rubric and evidence to substantiate for the scores they saw befitting a particular response. The researcher was given the role of overseer to decide the final score in a case where consensus could not be reached.

5.2.1. Pre and Post-intervention raw scores

The TSPCK scores generated for both pre- and post-TSPCK tests for the entire cohort are given in Table 5.1.

Table 5.1: Raw scores for OFTs' TSPCK tests in particulate nature of matter

Teacher	LP	CS	WD	RP	CT	Average. Person scores
1. Mary	1 (3)	1(3)	2 (3)	2 (3)	1 (2)	1 (3)
2. Harriet	2 (3)	1(1)	1 (3)	2 (3)	1 (3)	1 (3)
3. Nicky	1 (3)	2 (3)	2 (3)	1 (3)	1 (2)	1 (3)
4. Thabo	1 (3)	2 (2)	1 (2)	2 (3)	1 (3)	1 (3)
5. Andile	1 (3)	2 (3)	1 (3)	1 (2)	1 (2)	1 (3)
6. Merriam	2 (3)	2 (3)	3 (3)	3 (3)	2 (2)	2 (3)
7. Antana	2 (4)	2(3)	2 (3)	2 (3)	1 (3)	2 (3)
8. Noreen	2 (4)	1(3)	2 (3)	2 (3)	1 (3)	2 (3)
9. Sophie	2 (3)	1 (2)	2 (3)	2 (3)	1 (2)	2 (3)
10. Noxy	2 (3)	2 (3)	2 (3)	1 (2)	1 (2)	2 (3)
11. Amanda	2 (3)	1 (3)	1 (2)	1 (2)	1 (2)	1 (2)
12. Zukie	1 (3)	2 (2)	1 (2)	2 (3)	1 (2)	1 (2)
13. Litha	1 (2)	1 (2)	1 (2)	2 (3)	1 (2)	1 (2)
14. Nosipho	1(2)	2 (2)	2 (3)	2 (3)	1 (1)	2 (2)

15. Fiona	2 (3)	2 (3)	1 (2)	2 (3)	1 (1)	2 (2)	
Average per Component	**2 (3)**	**2 (3)**	**2 (3)**	**2 (3)**	**1 (2)**	**Av. Person score**	**1 (3)**
Average TSPCK component score						**2 (3)**	

*Pseudonyms have been used in the Table above to protect the identity of the participants

*Numerical values in brackets represent post-test scores

The five columns after the first column are the scores of the five components of the TSPCK where LP abbreviates the Learner Prior Knowledge, CS for Curricular Saliency, WD for What is Difficult to teach, RP for Representations and CT for Conceptual Teaching Strategies. The pre-test scores of the teachers are given outside the bracket on each pair of the scores given under each knowledge component. In the last column of the Table are average person scores for each teacher for both pre- and post-tests. Meanwhile, the average group scores for each of the TSPCK components are given in the last two rows at the bottom of the Table for both pre- and post-tests. These recurring patterns were further captured through the overall average person score of 1(3) as indicated at the bottom right corner of the Table.

As can be seen that there was a noticeable increase between the pre and post-test scores and a high level of homogeneity in the group. It is clear from Table 5.1 above that the recurring pattern in the pre-tests were score achievements of 1 which means Limited TSPCK. However, in the post-tests, the score achievements of 3 were the most dominating across the five knowledge components which meant developing TSPCK.

The average TSPCK component scores 2 (3) shown in the last row of Table 5.1 also reflect a positive shift in the understanding and interactive use of components. The average scores per the TSPCK components are represented through a pictorial representation as given in Figure 5.2. The X-axis shows the five TSPCK components and the average test scores per TSPCK component for pre- and post- intervention were plotted on the Y-axis.

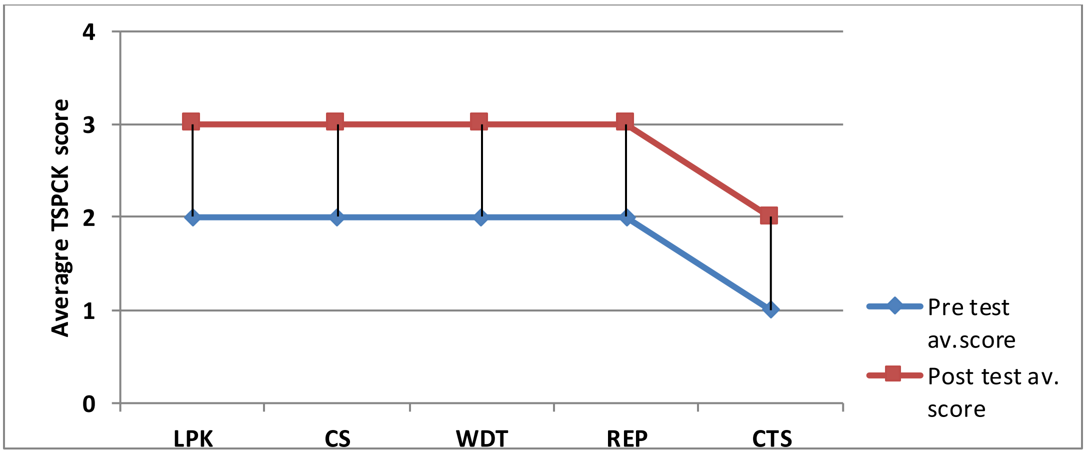


Figure 5.2: Average TSPCK components' scores pre and post the intervention

Two positive trends emerged from the analysis of the shifts in understanding and the interactive use of the TSPCK components. The first trend, the TSPCK components show a 1-category jump towards a higher quality of the TSPCK and this was on the component of the Learner Prior Knowledge, Curricular Saliency, what is difficult to teach and Representations. In these four knowledge components, the OFTs achieved an average score of 2 in the pre-tests and 3 in the post-tests which meant that they moved from the basic TSPCK to the developing TSPCK.The second trend was a shift in the component of Conceptual Teaching Strategies but, remained in the first two lower categories of the rubric that is, a shift from limited to basic TSPCK categories.

The following section shows that the individual scores yielded an average of 2-category jump in the component of Learner Prior Knowledge.

(i) Example 1: Pre (post) TSPCK test scores of the component of Learner Prior Knowledge

In the component of the LP, the OFTs experienced an average of 2-category jump between pre- and post-test. In this section, extracts from the OFTs written responses are used to substantiate the average scores of the component of the Learner Prior Knowledge. These extracts are used to provide evidence for examples of what a 2-category jump response looks like in the pre and post written responses as they the most representative of this component. Figure 5.3 shows a graphical representation of the individual person scores for the entire cohort in the component of the LP linked to the average test score on the Learner Prior Knowledge component.

Figure 5.3: Pre and post TSPCK individual person scores in the component of learner prior knowledge

In the graph of the Learner Prior Knowledge above, three trends emerge. The first trend shows that in the cohort of 15 OFTs, 7 teachers experienced a knowledge gain of a 2-category jump. In this category 3 OFTs experienced a jump from a score of 2 in the pre-tests to a TSPCK score of 4 in the post-intervention test while 4 OFTs showed a shift from a TSPCK score of 1 in the pre-tests and to a score of 3 after the intervention.

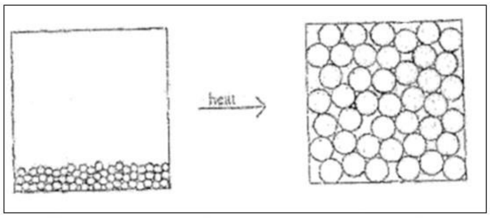
In the second and third trend, the OFTs experienced knowledge gain of 1-category jump, some from a score of 2 to 3 and some from a score of 1 to 2. However, it is important to note that a shift of 1 does not always mean the same thing since these are categories and not arithmetic measures.

For example, a 1-category shift from 1 to 2 is not as important as a shift from 2-3. For example, 6 OFTs who experienced a shift from 2 to 3 meant their responses were expanding and re-phrasing explanations using one other component of TSPCK interactively in the post-tests. This was an aspect which was missing in their pre-tests as a score of 2 meant their responses had no evidence of drawing on other TSPCK components.

On the other hand, the 2 teachers who made a shift from 1 to 2 meant that in the pre-tests such teachers were not able to identify and attempt to address the learner misconception. However, in the post-tests, these teachers were only able to identify the misconception but were using standardized definitions to address the misconception which is still not good enough according to the categories of TSPCK.

Therefore, the patterns in Figure 5.3 show that the OFTs experienced a differentiated growth in the component of the Learner Prior Knowledge, which was overall. The analysis below, shows qualitative responses that correspond to one of the observed patterns in Figure 5.3. This shows a teacher response that reflects a 2-category jump. In the category of Learner Prior Knowledge, the OFTs were presented with a classroom scenario where learners were asked to represent the change that takes place when a substance is heated and where a particular learner gave a response that highlighted a misconception in understanding this concept. The OFTs were then asked to comment on the learner's response. An extract from the TSPCK tool is given in Figure 5.4 below.

1. Learners in a grade 8 class were asked to represent the change that takes place when a substance is heated. The response Thabo has written on the board is shown below.



How would you comment on Thabo's response as part of an explanation to the rest of the class?

Response A: Thabo's response is incorrect. All substances have small particles called atoms that may combine chemically with each other to form molecules. When substances are heated their molecules do not expand in size. The size of the molecules stays the same.

Response B: Thabo's response is incorrect. When a substance is heated, molecules gain kinetic energy. The molecules will start vibrating and the bonds between them weaken to allow re-arrangement and in some cases allowing the molecules to move away from each other. The molecules themselves do not change in size when heated. It is the re-arrangement of molecules that changes.

Response C: Thabo's response is incorrect. When a substance is heated, a phase change occurs. The molecules of a substance become more free from each other as the bonds are weakened in some cases completely broken. Substances that were originally solids may become liquids and liquids may become gases

Response D: None of the above

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

Figure 5.4: Extract from the TSPCK tool on particle nature of matter

To provide further evidence for the observed jump of 2 jump trend above, teacher Noreen' s response on Learner Prior Knowledge prior and post the intervention are given in Figure 5.5.

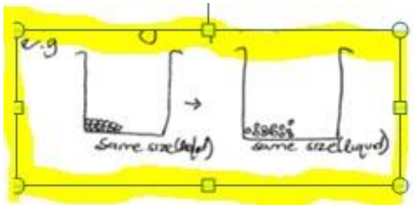
Extract from pre-test tool	Extract from post-test tool
C: When a substance is heated, size does not change. It is the arrangement of particles that changes. In a solid-state particle are arranged closer together & as they are heated they become further apart	B: When molecules are heated they gain kinetic energy. They start to collide with each other and cause them to vibrate. As the molecules get more heat they will occupy more space. In the process of doing this, molecules remain the same in size and they do not break. They only change their arrangement, and shift their original positions. 

Figure 5.5: Teacher Noreen's responses in the pre and post TSPCK tests in the component of learner prior knowledge

- **Learners' Prior Knowledge before the Intervention**

Figure 5.5 above is teacher Noreen's written responses from her pre and post the intervention of the completed TSPCK tool. These extracts show the difference in the depth of her response, from the mere regurgitating of facts to emphasis of important understanding and confrontation of the incorrect understanding. For example, in the pre-test response given by teacher Noreen, the teacher chose option C as a way of dealing with the misconception presented in the TSPCK tool. Option C does not deal with the misconception per se, except stating that *phase change occurs and molecules become freer* without dealing with the fact that the student thinks that during phase change, particles themselves increase in size. It is simply a statement of content facts. Therefore, option C does not go deeper into explaining the concept of phase change at the particle level. Teacher Noreen further makes a very abstract statement as indicated in Figure 5.5 above stating that: '*Once the particles are heated they become light and vibrate starting to move'*. In this way, teacher Noreen according to the rubric provides an explanation which only makes use of a factual content that is seen as an element of **Curricular Saliency** without drawing interactively from other components, and thus was awarded a score of level 2 (basic TSPCK).

- **Learner Prior Knowledge post the Intervention**

In the post-TSPCK tests, teacher Noreen changed her choice from the provided options and now opted for B as befitting explanation to the learner misconception as opposed to C in pre-tests. While all the options provided for this item are correct but B is deemed as most befitting, in that while it unpacks the concepts of phase change during heating, it draws deeply on Curricular Saliency (CS) with the Learner misconception (LP). However, in the post-intervention test, teacher Noreen's expanded response is evidence of the three TSPCK components that are used interactively in formulating explanations in planning to teach context. The teacher draws from her knowledge of her Curriculum Saliency (CS) in scientifically explaining the concept of the effect of temperature increase during phase change using the following words '*When molecules are heated they gain* *kinetic energy. They start to collide with each other and cause them to vibrate. As the molecules get more heat they will occupy more space.*

The teacher does not only use the correct scientific concepts in particulate nature of matter to address this misconception but further makes use of the Learner Prior Knowledge (LPK). The teacher acknowledges Learner misconceptions and makes a statement to correct it before stating what happens through the following statement: *In the process of doing this, molecules <u>remain the same in size and they do not break</u>, they only change their arrangement, and shift their original positions.*

The teacher finally makes use of a diagram to provide for learner visualisation of what happens to molecules as they are heated. The teacher draws molecules of the same size with different arrangements in liquid and solid phase and thereby drawing from the knowledge of Representations (RP) to formulate an appropriate response that deals with learner misconception. This showed evidence of exemplary TSPCK quality after the intervention. The example with teacher Noreen is a typical development in the shift experienced by the OFTs who were demonstrating a 2 category jump in the component of Learner Prior Knowledge.

ii) Example 2: pre and post intervention-TSPCK tests in the component of Curricular Saliency

The three TSPCK components namely, Curricular Saliency, What is difficult to teach and Representations formed part in the second trend where that was observed in a 1-category jump towards the higher level of the TSPCK. This analysis, starts by explaining the shifts observed in the Curricular Saliency. In Figure 5.6 are the OFTs' person scores which resulted in the entire cohort achieving an average score of 2 pre the intervention and 3 post the intervention.

Figure 5.6: Pre and Post TSPCK person scores in the component of Curricular Saliency

In Figure 5.6, the majority of the OFTs were awarded a score of 2 before the intervention with 8 out of 15 teachers of this cohort achieving this score. The majority (9 teachers) of this cohort achieved a score of 3 after the intervention. The rest of the cohort achieved a score of 1 pre- and 2 post- the intervention. These were the contributing factors to the overall 1 category jump towards the higher level of TSPCK as revealed in the overall average score of 2 (3) pre and post the intervention for the component of Curricular Saliency. Teacher Antana's written responses are used as an example of a written response which portrayed the 1-category jump into the higher 'developing' category since this was the most recurring trend in data analysed of OFTs.

Curricular saliency as depicted in the TSPCK framework is important for the development competence needed by teachers in transforming and engaging concepts in particulate nature of matter. Curricular saliency in a specific topic emphasizes the 'big ideas' (main concepts), the order of teaching these main concepts, mapping the manner in which they link to their respective sub-ordinate concepts, the importance of the topic and why it must be taught, and the pre-concepts that are to be in place for the understanding of the topic. The TSPCK item that was used to make the OFTs' knowledge of Curricular Saliency was built around these factors. Figure 5.7 is an example of a written response by teacher Antana when teachers were asked to portray their understanding concerning their Curricular Saliency in the topic of particulate nature of matter prior to the intervention. The example in Figure 5.7 illustrates the OFTs level of interaction of the TSPCK components in their responses.

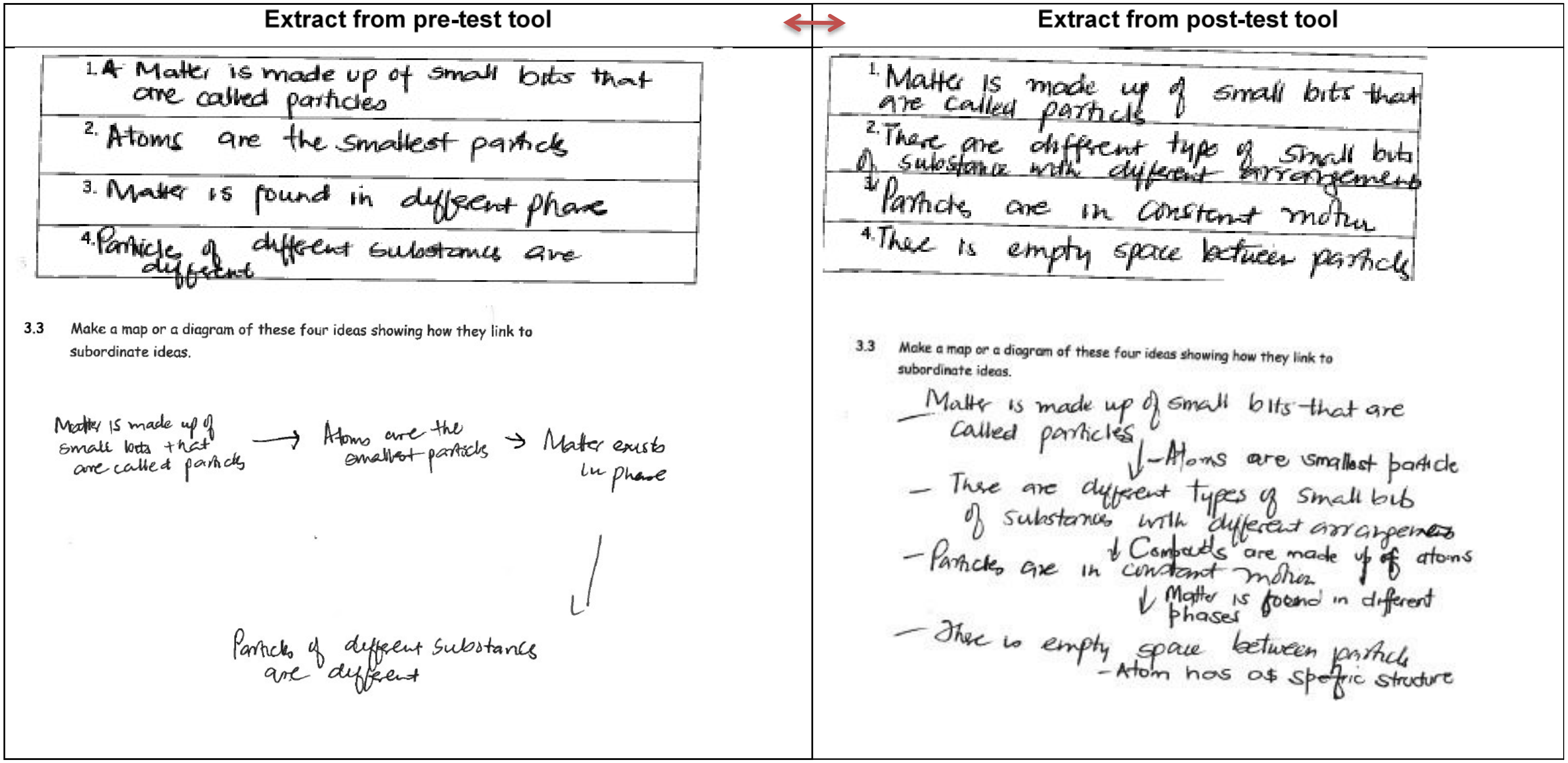


Figure 5.7: Teacher Antana's responses in the pre and post TSPCK tests in the component of Curricular Saliency

- **Curricular Saliency Prior to the Intervention**

In Antana's response above, the initial list of big ideas is a mixture of 'big ideas' and subordinate ideas. For example, the concept of '*Atoms are the smallest particles'* is understood in the topic of the particulate nature of matter as a sub-ordinate idea, rather than a main/big concept.

While the topic of particulate nature of matter revolves around the concept of "atom", this concept alone does not describe the overarching definition in teaching the topic, but it is a concept that seeks to clarify and expand on the main idea which entails *'matter as being made up of small bits called particles'.* Therefore, the idea that *'atoms being the smallest particles'* is only seeking to elaborate on the meaning of the small bits that make up matter but not the main concept on its own. The mix-up in big ideas and sub-ordinate ideas is a sign that Antana was not able to differentiate between big ideas and sub-ordinate ideas in the topic. The sequence of teaching these main ideas as proposed by teacher Antana makes no logic because in the provided mapping the map omits the sub-ordinate ideas but repeats the main ideas chosen in the first question without any links.

This mix up affected the sequencing and linking of main ideas and sub-ordinate ideas in the topic, not only in Antana's response but with the majority of the OFTs in this study. This affirms the underpinning results in the literature review that states that teachers who are teaching topics out of the field of their training tend to have weak content knowledge with a superficial approach in their dissemination of content knowledge. This also ratifies the need for interventions such as the one proposed in this study to expose the OFTs to professional development programmes that seek to engage the OFTs with knowledge development that can assist them to deepen their curriculum awareness of CK in the particulate nature of matter.

The central aspect which determines the quality of the TSPCK is reflected by the OFTs written responses and is evidence of drawing on the other TSPCK components to formulate responses and this aspect was missing in teacher Antana's responses. Thus, teacher responses were identified as reflecting basic TSPCK which means the only visible component in this response is that of their Curricular Saliency. Since there was no evidence of drawing from any other TSPCK components except her **Curricular Saliency**, teacher Antana was awarded a score of 2.

- **Curricular saliency immediately after the intervention**

OFTs' written responses gave evidence that as the intervention was proceeding, teachers' TSPC was developing compared to their TSPCK at beginning of the intervention. The confidence in teachers to express themselves with regards to the concepts of particulate nature of matter indicated that there were shifts in their knowledge competence needed to transform CK in the topic. The developing pedagogical competence in the OFTs was a process of both struggle and success, through trial and error. There were instances of both failure and success. For example, in the qualitative analysis above, it was evident that the OFTs struggled to develop their TSPCK through Curricular Saliency as a starting point as the majority of their written responses failed to depict emerging component interactions to Curricular Saliency.

However, few of the OFTs' written responses under Curricula saliency showed evidence of developing TSPCK. Antana's written response was used to illustrate a representation of developing competence immediately after the intervention. For example, post the intervention, Antana's written response above is portraying evidence that immediately after the intervention she was able to make a clear distinction between big ideas and sub-ordinate ideas in that all the chosen big ideas were appropriate and not mixed with sub-ordinate ideas. This distinction is further supported by the fact that at the end of the intervention Antana was able to attempt to link the big ideas with corresponding sub-ordinate ideas. The linking of big ideas with sub-ordinate ideas is an important attribute of developing TSPCK to Curricular Saliency but none of the e OFTs were able to make this attempt at the beginning of the intervention. This linking and understanding are pivotal for teacher's knowledge of Curricular Saliency and in turn TSPCK development of teachers in understanding their content knowledge deeper.

Firstly, how teacher Antana proposed her order of teaching these big ideas is a revelation of a teacher who can now see a bigger picture of teaching particulate nature of matter. The first proposed big idea is a definition of what matter is and what constitutes matter thereof. It is impossible for one to even go deeper in teaching the topic without understanding the definition of matter at the particle level; thus, the concept of '*Matter is made up of small bits called particles'* is on its own holding a highly definitive power of providing understanding to the particulate nature of matter. It makes sense to propose this big idea as the first big idea in teaching this topic. Furthermore, Antana proposes 'Atoms are the smallest particles' as the sub-ordinate idea to this big idea. It is important to recall that at the beginning of the intervention this teacher proposed 'Atoms are the smallest particles' to be one 'big idea', but post the intervention there is a clear distinction and Antana is even able to understand that this sub-ordinate idea also connects to the big idea that it seeks to explain. This was the case with all the big ideas Antana chose, as shown in Figure 5.7 above.

Teacher Antana managed to make acceptable links between the sub-ordinate and big ideas and a logical sequence thereof. It is evident from Antana's written response that she is acknowledging Learner Prior Knowledge in her responses and thus provides a clear picture of how this topic is structured to help students understand the overall aim of teaching the topic. Antana further acknowledged the importance with reasons of understanding the topic of the particulate nature of matter which shows the sequential development of concepts. There is a deeper curriculum structure depicted in Antana's response as compared to the written responses of the same test at the beginning of the intervention. There were shifts observed in the written response post the intervention which led to a score of 3, showing evidence of developing TSPCK.

iii) Example 3: Pre and post TSPCK test scores in the component of What is difficult to teach

Another important aspect of the construct of TSPCK is the knowledge component of What is Difficult to teach. A list of different concepts under the topic of the particulate nature of matter was provided to the teachers and they were expected to choose from the list they regarded difficult to teach or learn. The concepts on the topic of particulate nature of matter were mixed with sub-concepts. In addition to the question, teachers were expected to provide reasoning for their choices. The OFTs experienced a 1 quality category jump. In the Figure 5.8 is the graphical representation for pre and post TSPCK scores for the entire cohort on the component of What is Difficult to teach.

Figure 5.8: Pre and post TSPCK person scores in the component of what is difficult to teach

The majority of the OFTs scored 2 pre and 3 post the intervention and this contributed to the average component score of 2 and 3 for the entire cohort in the knowledge component under discussion. The importance of a shift in knowledge from a score of 2 to 3 is shown by the fact that a written response that was scored a 2 would mean the teacher “identifies specific concepts but provides broad generic reasons”. Such a response is categorized as portraying basic TSPCK according to the rubric designed to score teacher questionnaires in this study. The shift to score 3 would also mean that a teacher has moved from giving just generic reasons but is now able to provide reasons relating to one other TSPCK component. For example, teacher Mary’s written response in the pre-tests was as follows:

Table 5. 2: Extract of a written response scored 2

Concept	**What makes it exactly difficult**
There is an empty space between particles	The concept is so abstract but chart (teaching aid) try to make it clear
Particle bombardment with the walls of the container causes pressure in gases	I need to understand it myself

In the written response above, teacher Mary provides a generic response without providing any specific reasons for learner difficulty, thus scored 2 which means basic TSPCK, but this changed in the post-tests. In Table 5.3 is teacher Mary’s response in the post-tests.

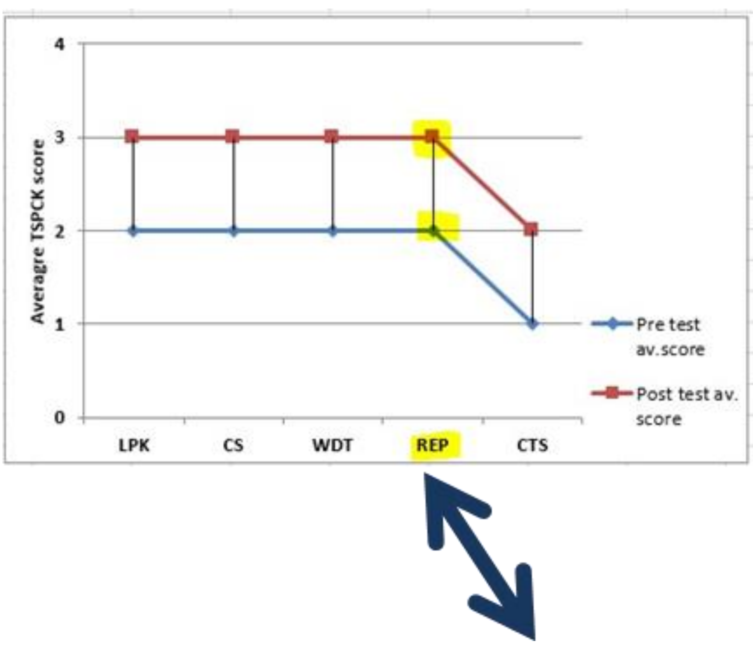
Table 5. 3: Extract of a written response scored 3

Concept	**What makes is exactly difficult**
There is an empty space between particles	To identify that there are spaces between gases molecules
Particle explanation for change of state	They don’t understand that particles cannot change in size

In the post-tests, teacher specifies the reasons for learner difficulty in teaching the concept of “*there is an empty space between particles of matter*’. The reasons provided are based on visualization. According to Bucat (2004), visualization of the structure of molecules is a common problem in the topic of organic chemistry; however, the concept of empty spaces touches on the structure of molecules in particle nature as well that makes visualization a problem in this topic too. Furthermore, for learner difficulty in the concept of ‘*particle explanation for change of state’,* teacher Mary’s reason is providing reasons related to Learner misconceptions about change in the size of particles during phase change. Thus, such a response was scored a 3 which demonstrates developing TSPCK post the intervention. This method of analysis was used to analyze the rest of teacher written responses in this category.

iv) *Example 4: Pre and Post TSPCK test scores in the component of Representations*

The third knowledge component from which teachers experienced 1 jump shift towards the higher TSPCK was knowledge of Representations The Figure 5.9 is a graphical representation of the entire cohort's scores pre and post the intervention for the knowledge component of Representations which led to a 1-jump shift in the quality of TSPCK scores of OFTs from 2 to 3.



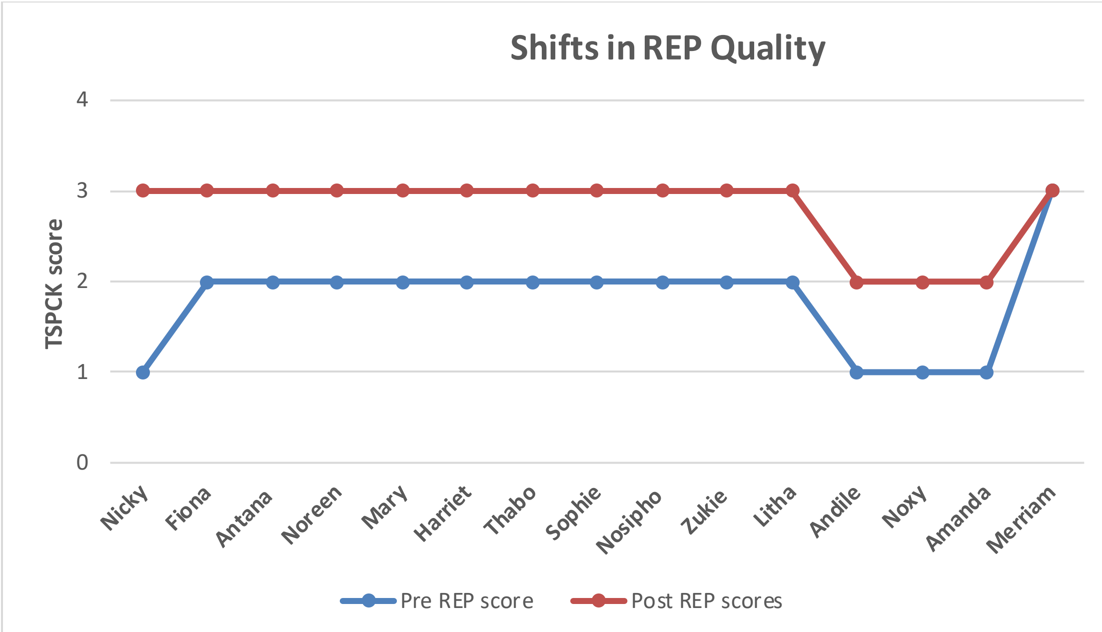


Figure 5.9: Pre and post TSPCK person scores in the component of representations

Figure 5.9 above is a pictorial representation of the entire cohorts' scores for pre and post the intervention in the knowledge component of representations that shows that the majority of the OFTs experienced a 1-jump shift from a score of 2 to 3. In the pre-tests, the majority of the OFTs were limited to the use of macroscopic representation without explanatory notes to make links to the concept being explained. This category matched the majority of the OFTs in the pre-tests which was scored as 2 to show the basic TSPCK.

However, this changed in the post-tests as the majority of the OFTs written responses were now showing developing the TSPCK, scoring 3. A score of 3 meant that they were able to make use of microscopic and symbolic representations with explanatory notes linking the two representation to aspects of the concept being explained. It also meant the OFTS were able to reference these representations to one others' TSPCK component. An example of teacher response scored as 2 in the pre-tests and 3 in the post-tests is teacher Nosipho and the details of the analysis which led to her responses being awarded these scores is given in Appendix 12.

iv) ***Example 5: Pre (post) TSPCK test scores in the component of Conceptual Teaching Strategies***

In this knowledge component, the OFTs experienced a 1-jump shift but still in the lower categories of the TSPCK. The Figure 5.10, is a plot of the pre and post TSPCK scores on teaching strategies. These are the individual scores that resulted in the average TSPCK scores of 1 pre and 2 post the intervention in the component of teaching strategies as depicted in the TSPCK component graph.

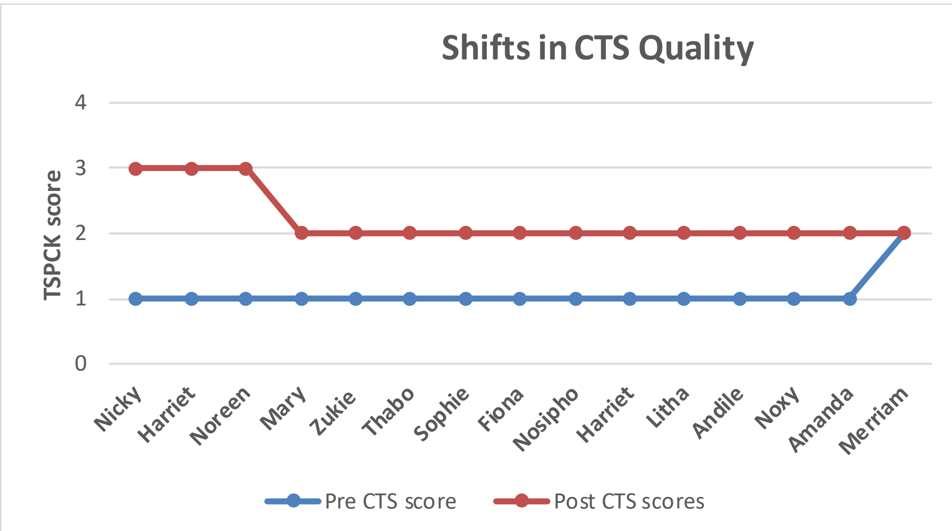


Figure 5.10: Pre and post TSPCK individual person scores in the component of conceptual teaching strategies

As seen in Figure 5.10 above, the OFTs experienced a shift in the knowledge of teaching strategies. An average score of 1 in the pre-tests meant the majority of the OFTs scored 1 which meant their written responses portrayed the Limited TSPCK. Limited TSPCK meant that the OFTs showed no evidence of acknowledgement of the student Prior Knowledge and misconceptions. The majority of the OFTs responses were lacking in the aspects of curriculum saliency and their use of representations was limited to macroscopic or symbolic scientific representations.

However, in the post-tests, the majority of the OFTs scored 2 which meant the basic TSPCK. This implies that post the intervention the OFTs were able to acknowledge student misconceptions verbally with no corresponding confrontation strategy.

Additionally, their responses lacked the aspects of Curricular Saliency and the use of macroscopic and symbolic representations with no linking explanatory notes.

An example of teacher response scoring 2 in the pre-tests and 3 in the post-tests is teacher Nosipho and the details of the analysis which led to her responses being awarded these scores is given in Appendix 13.

5.2.2 Improvement across the person average scores

To establish the impact of the intervention on the interactive use of the TSPCK components for each teacher, the average scores for the individual OFTs were calculated. The graphical representation of this analysis is given in Figure 5.11. In the analysis of overall interactions of the OFTs' use of the TSPCK components as reflected by group average scores across different components, one can deduce that there is an observable shift of at least 2 category jumps across most of the OFTs (7 out of 15). This implies that the most recurring trend was that of written responses which portrayed limited TSPCK (1) prior the intervention to developing TSPCK (3) post the intervention

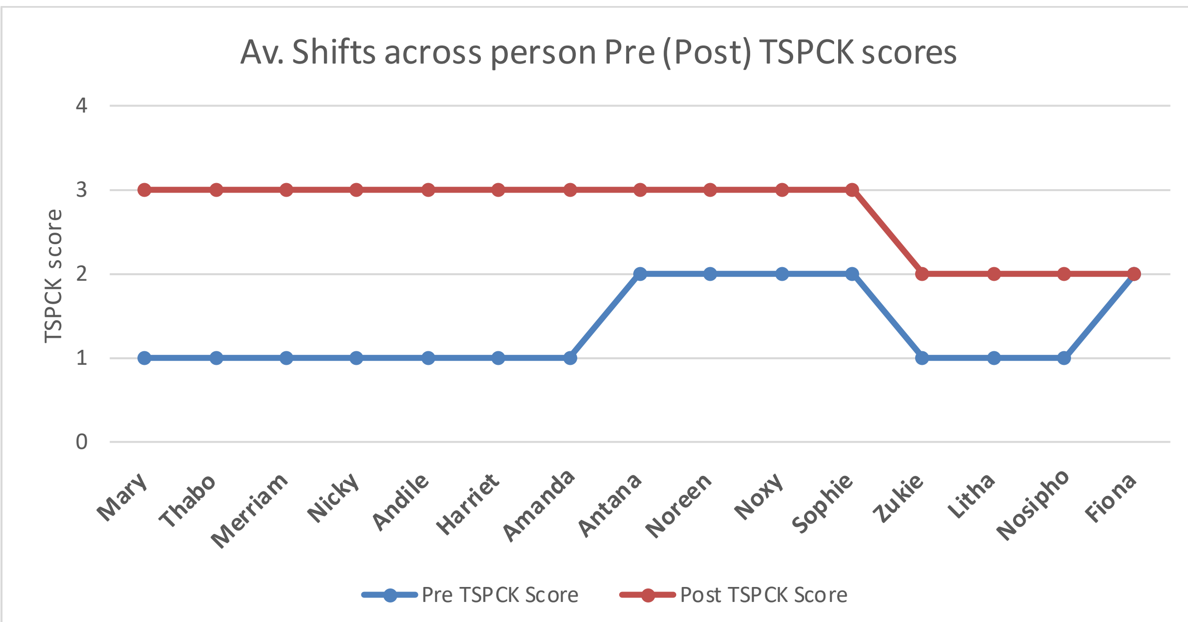
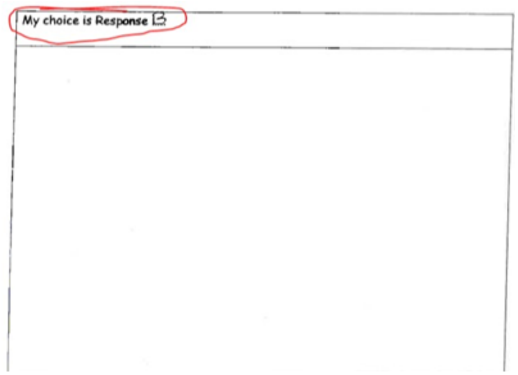
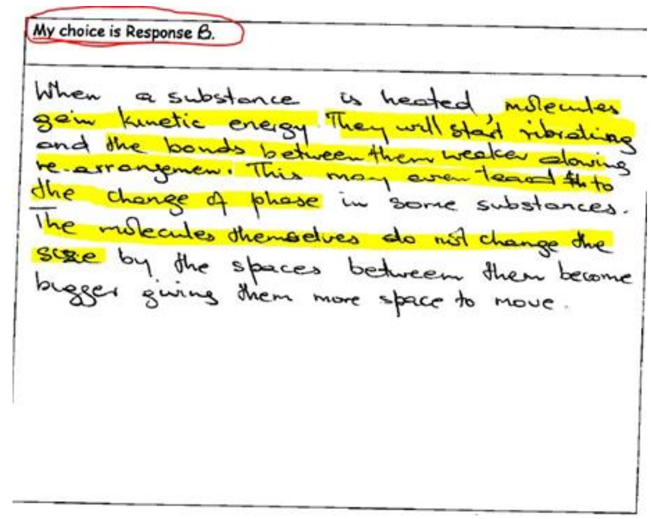
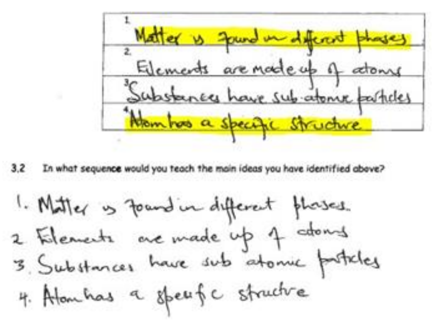
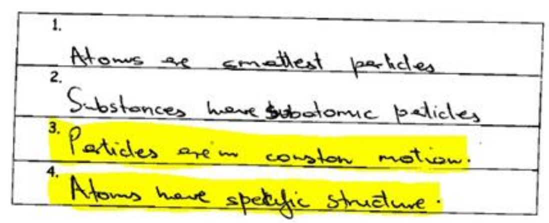


Figure 5.11: Average person pre and post the intervention TSPCK scores

Figure 5.11 shows that four visible trends emerged from the data and these trends represent varying knowledge gained by the OFTs across all knowledge components. It is important to note that the average individual scores calculated in Table 5.1 above reflect teacher performances for the interactions arising from each component. These interactions together, give an overall picture of the use of the TSPCK components in the explanations in the TSPCK tests that are aligned with the theoretical framework of this study.To substantiate the evidence in the overall shift of the quality of the TSPCK as per analysis above, an extract of teacher Harriet's written responses for pre-test vs post-tests were further analysed on each of the TSPCK components. In this example, the emphasis was on providing evidence for qualitative analysis that led to the determination of the teachers' interactive use of the five TSPCK components through the individuals' average score. Teacher Harriet was used an example and this was done for all questionnaires.

Table 5.4: Teacher Harriet's summary responses in the pre and post TSPCK tests

CASE: A positive overall shift of 2 category towards the higher quality category	**EXTRACTS FROM PRE INTERVENTION**	**EXTRACTS FROM POST INTERVENTION**
 	Learner Prior Knowledge  My choice is Response B	Learner Prior Knowledge  My choice is Response B. When a substance is heated molecules gain kinetic energy. They will start vibrating and the bonds between them weaken allowing re-arrangement. This may even lead to the change of phase in some substances. The molecules themselves do not change the size by the spaces between them become bigger giving them more space to move.
 	Curricular Saliency  1. Matter is found in different phases 2. Elements are made up of atoms 3. Substances have sub-atomic particles 4. Atom has a specific structure 3.2 In what sequence would you teach the main ideas you have identified above? 1. Matter is found in different phases. 2 Elements are made up of atoms 3. Substances have sub atomic particles 4. Atom has a specific structure	Curricular Saliency  1. Atoms are smallest particles 2. Substances have subatomic particles 3. Particles are in constant motion. 4. Atoms have specific structure.

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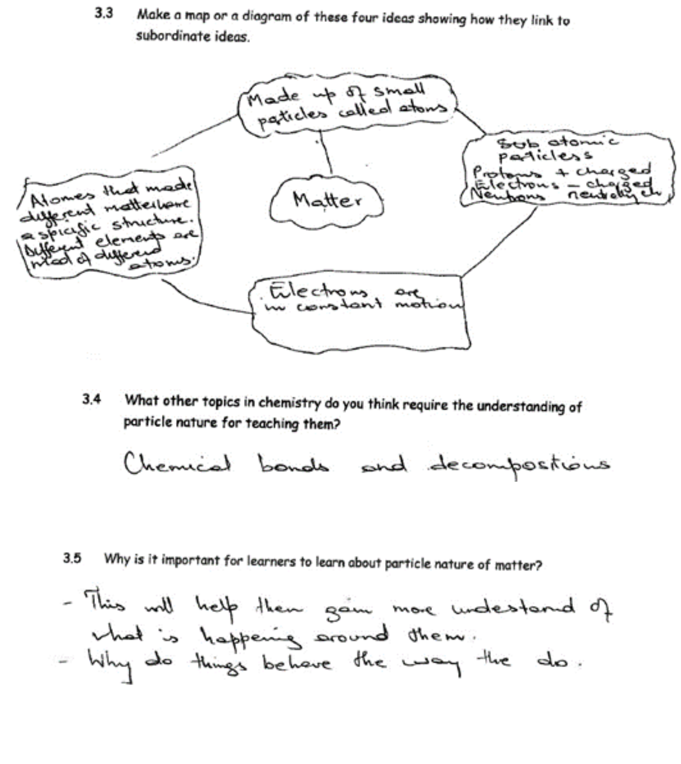
<td>

3.3 Make a map or a diagram of these four ideas showing how they link to subordinate ideas.

3.4 What other topics in chemistry do you think require the understanding of particle nature for teaching them?

Chemical bonds and decompostions

3.5 Why is it important for learners to learn about particle nature of matter?

- This will help them gain more understand of what is happening around them.
- Why do things behave the way the do.</td>
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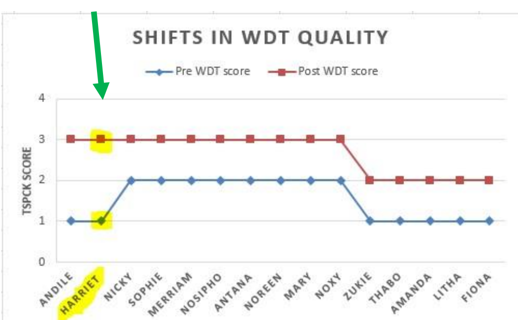
<td>
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<td><u>What is difficult to teach</u></td>
<td><u>What is difficult to teach</u></td>
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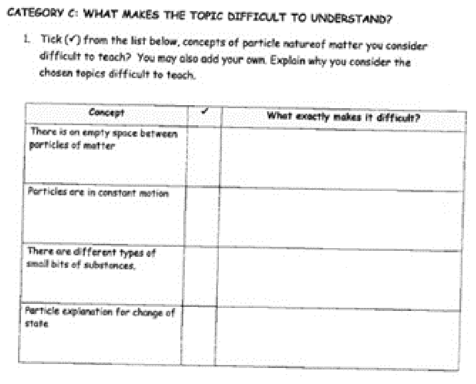
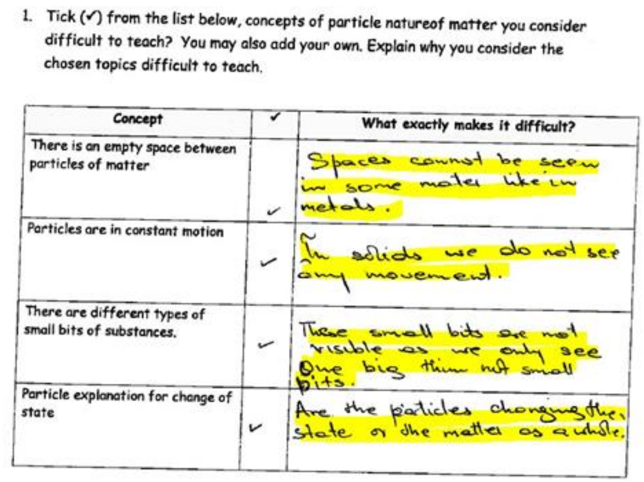
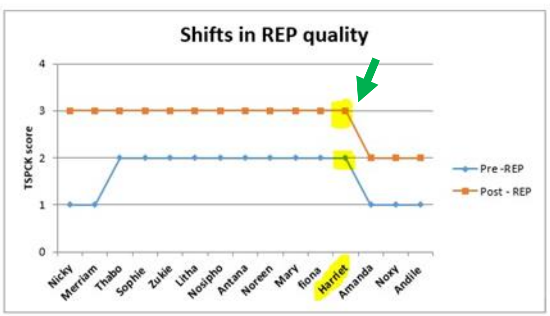

CATEGORY C: WHAT MAKES THE TOPIC DIFFICULT TO UNDERSTAND?

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

Concept	✓	What exactly makes it difficult?
There is an empty space between particles of matter		
Particles are in constant motion		
There are different types of small bits of substances.		
Particle explanation for change of state		

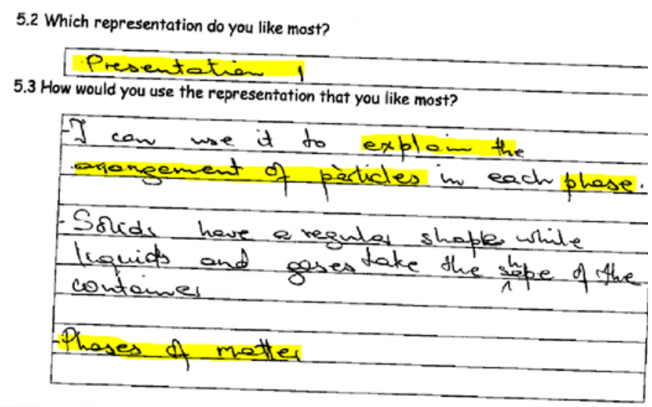

1. Tick (✓) from the list below, concepts of particle natureof matter you consider difficult to teach? You may also add your own. Explain why you consider the chosen topics difficult to teach.

Concept	✓	What exactly makes it difficult?
There is an empty space between particles of matter	✓	Spaces cannot be seen in some matter like in metals.
Particles are in constant motion	✓	In solids we do not see any movement.
There are different types of small bits of substances.	✓	These small bits are not visible as we only see one big thing not small bits.
Particle explanation for change of state	✓	Are the particles changing the state or the matter as a whole.



Representations

Representations


5.2 Which representation do you like most?

Presentation

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

I can use it to explain the arrangement of particles in each phase.

Solids have a regular shape while liquids and gases take the shape of the container

Phases of matter

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

Representation No.	What I Like	What I do not like
1	I like this presentation because it shows both the picture of these phases and how particles are arranged in each phase	
2		Does not show arrangement of particles in the phases of matt
3	It shows how the particles are arranged in each phase.	

5.2 Which representation do you like most?

Presentation 1

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

It can bring to my class this picture together with real objects to class. It can clearly sh[ow] that there are spaces between the particl[es]

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		Teaching strategy - telling and demostration - I would tell the learnes that air evenly feels the conteiner. It can not be concentrated in a specific area. - Gas particles continuously move from the region of hig concentration to the area of low concentration until all the air is the same. - If the air was compresses and and the other air is sucked out the remaining particles will then re arrange filling the container again evenly. I would also demonstrate this by letting them blow a baloon and feel its hardness when it is full of air that air is not only concentrated to a certain area making the baloon more harder at some places. After that let them release some air out and let them feel it again that the remaining air particles have again been evenly distributed in the baloon.

In Learner Prior Knowledge, Harriet's response was scored a 2 that meant she had basic TSPCK in the pre-tests. This changed to a score of 3 in the post-tests that meant that she had a developing TSPCK. According to the rubric that was used to score these instruments, it meant that the response given by teacher Harriet at the beginning of the intervention had no evidence of drawing on other TSPCK components. However, the shift in score post the intervention meant teacher Harriet was able to expand and re-phrase explanations using one of the other TSPCK components interactively. In the written response of teacher Harriet, there is the use of her Curricular Saliency interactively with her Learner Prior Knowledge to address a misconception. This meant an increase in knowledge in the interactive use of the TSPCK components to formulate explanations to address learner misconception and therefore was awarded a score of 3 post the intervention.

In the knowledge component of Curricular Saliency, the determining factors for higher quality levels according to the rubric for this item was the identification of Big Ideas together with valid reasoning as well as interactive use of one or more TSPCK components in formulating explanations. In the pre-tests, teacher Harriet only provided a list of Big Ideas that was a mix of Big Ideas and sub-ordinate ideas. The sequencing, therefore, is of no value as it was a mix of Big Ideas and sub-ordinate ideas. This written response scored 1 that meant she had limited TSPCK. In the post-tests, the teacher scored 1 again which meant she still had limited TSPCK.

Firstly, the sequencing made by this teacher had two illogical placings of Big Ideas. However, in the post-tests, teacher Harriet could link the topic to other topics in chemistry that require an understanding of the particulate nature of matter as she mentioned *"chemical bonds [bonding]"* in her response. For the importance of the topic, she stated that *"this will help them gain more understanding of what is happening around them. Why do things behave the way they do"?*

The topic of the particulate nature of matter revolves around interpreting 'behaviour' of matter around our day-to-day life through the use of the particle model as a scientific explanation. The reasons given by teacher Harriet exclude conceptual considerations and show no evidence of drawing on the other TSPCK components thus she was awarded a score of 1.

In the knowledge component of What is difficult to teach, teacher Harriet scored 1 in the pre-tests which meant she had limited TSPCK because she gave no reasons for learner difficulty in the concepts provided for the item. Since the rubric was designed to score the tests had no scale at 0 but all started at level 1, therefore teacher Harriet was awarded a score of 1.

In the post-tests, teacher Harriet was able to identify specific concepts leading to learner difficulty. Teacher Harriet's reasons for learner difficulty were reflecting the use of her Curricular Saliency and in some cases knowledge of her Learner Prior Knowledge to explain the concepts which are difficult to understand and teach by nature. This meant these reasons relate to one other TSPCK component. Thus, in the post-tests, teacher Harriet was awarded a score of 3 that meant developing TSPCK and developing interactive use of other components in engaging What is difficult to teach in the topic of particulate nature of matter.

In the knowledge component of Representations, teacher Harriet was scored a 2 in the pre-tests which meant Basic TSPCK and Developing TSPCK in the post-test that meant a score of 3. In the pre-tests, teacher Harriet is making use of macroscopic representation and scientific symbolic representation without valid explanatory notes which links to the aspect of the concept being explained. Harriet talks about arrangement of particles at a generic level than being specific to what she would exactly teach about the arrangement of particles and why this is important for teaching the topic. The reasoning she suggested for her choice of representation also does not show how she would conduct a lesson around the concept depicted by this representation or how this representation would be useful in her teaching. This statement shows how Harriet would use representation 1 to teach "*it can bring to my class this picture together with real objects to class. It can clearly show that there are spaces between the particles*."

However, there was a shift in teacher Harriet's knowledge of representations in the post-tests. There is evidence of drawing from other TSPCK components to provide detailed use of these Representations in formulating teacher explanations. The reasons provided by Harriet are related to her Learner Prior Knowledge and cautioning about possible learner misconceptions that each of the Representations might bring.

Teacher Harriet's post-intervention responses also revealed clarity of mind in terms of articulating the manner she would use the Representation of her choice to explain the concept of particle arrangement at different phases. This means the teacher is drawing from her knowledge of Curricular Saliency. The written response of teacher Harriet gives evidence of the interactive use of two and more of the TSPCK components used simultaneously to plan to teach phases of matter. The teacher is specifically focusing on specific content that describes the particle arrangement and forces of attractions between particles in phases of matter. Harriet is, therefore, linking the Representations to her relevant Curricular Saliency while also being aware of the possible Learner misconceptions that might arise. Thus, this written response scored a 3 in the post-tests.

In the knowledge component of Teaching Strategies, teacher Harriet had a blank in the pre-tests. In the post-tests, there was a shift in teacher Harriet's written response to a score of 3 which meant Developing TSPCK. However, in the post-intervention tests, teacher Harriet puts it upfront that in her teaching strategy, two aspects that will be incorporated are explanations *[telling]* and demonstrations *"teaching strategy – telling and demonstrations".* The teacher explanation is confronting the Learner Prior Knowledge by stating, "*I would tell the learners that air evenly feels [meaning fills] the container. It cannot be concentrated in a specific area*". These are aspects of Curricular Saliency that the teacher draws from in dealing with Learner misconceptions.

Teacher Harriet then makes use of macroscopic Representations through a demonstration in explaining the concept of particulate nature of matter at the gaseous phase. The teacher demonstration is used to illustrate the movement of particles in the balloon firstly by filling up the balloon and after they released some air out. The teacher further makes learners feel the balloon at these different points to illustrate the concept of even re-arrangement of gas particles at these two points. The teacher is using knowledge of Representations interactively with Curricular Saliency to explain to the learners.

There was a continuous use of the following terms to emphasize some aspects of her Curricular Saliency related the concepts. Such repetition was seen in statements such as: (i) *"air evenly feels [meant to say fills] the container"*

(ii) particles will then rearrange filling the container evenly

(iii) remaining air particles have again been evenly distributed in the balloon".

Also, teacher Harriet demonstrates her knowledge of Learner Prior Knowledge including misconceptions in her repeated use of the statements such as:

(i) "cannot be concentrated in a specific area"

(ii) gas particles continuously move from the region of high concentration to the area of low concentration"

(iii) not only concentrated to a certain area.

Thus, she was awarded a score of 3 to show her developing TSPCK.

In the discussion above, it is evident that in the pre-tests, most of the time teacher Harriet's written responses were reflecting a teacher with limited TSPCK as she was scored a 1 for most of the components. In the post-intervention tests, for most of the components, teacher Harriet's written responses reflected a teacher with developing TSPCK. The written responses of teacher Harriets' explanations after the intervention had evidence of drawing from one other component. This explains the average individual score of 3 which denotes developing TSPCK post the intervention. This method of analysis was followed for the entire cohort.

5.3 Analysis for quantitative shifts using Rasch statistical Model

As alluded to in the previous discussions that the main purpose for this chapter was to respond to the second research question that asked the impact of the intervention on the quality of personal PCK in the topic of intervention. This meant that for this study to establish such an impact there must be a reliable and valid instrument used at the beginning and at the end of the intervention to measure the impact. The Rash statistical model was used to provide evidence for the construct of validity, reliability and unidimensional of the instruments.

Rasch provides linear rating scales and equal-interval data to avoid basing the Rasch model's strength of providing evidence about person-item measure based on unidimensional as an underlying assumption was key to this study. The unidimensional in the Rasch model assumes that all items in the tool work together to measure a single construct which validates the measurements. This underlying assumption of unidimensional was used to verify whether the components of TSPCK were all working together to measure the TSPCK in particulate nature of matter and thereby validating person reliability and item reliability through fit statistics.

- ***Person Fit Statistics***

The model was used in this study to produce a score which summarizes a persons' ability on a variable which was the TSPCK in the particulate nature of matter. The analysis yields informative visuals on the same metric in which both person proficiencies and item difficulties can be compared. Thus, the raw score data which was generated from the discussions above was then subjected to Rasch statistical model for quantitative analysis. In Figure 5.13 and 5.14 are fit statistics for person measures for pre and post the intervention.

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
3	12	5	3.95	1.01	.75	-.8	.62	-.2	.49	.46	80.0	67.2	NTUO
4	9	5	-2.45	3.40	.02	-1.1	.01	-1.1	.99	.94	100.0	98.2	FZWO
5	8	5	-5.88	1.18	1.02	.2	.74	.3	.63	.63	80.0	80.2	MBLO
6	8	5	-5.88	1.18	1.02	.2	.74	.3	.63	.63	80.0	80.2	MKBO
9	8	5	-5.88	1.18	.82	-.1	.56	.1	.67	.63	80.0	80.2	ARSO
10	8	5	-5.88	1.18	1.46	.9	1.83	1.0	.49	.63	80.0	80.2	NDLO
12	8	5	-5.88	1.18	1.02	.2	.74	.3	.63	.63	80.0	80.2	MNYO
2	7	5	-7.04	1.03	.95	-.1	.75	.2	.45	.44	80.0	68.3	ZOZO
7	7	5	-7.04	1.03	.78	-.9	.61	.0	.49	.44	80.0	68.3	NQDO
8	7	5	-7.04	1.03	1.32	1.2	1.09	.5	.36	.44	40.0	68.3	JKWO
11	7	5	-7.04	1.03	.78	-.9	.61	.0	.49	.44	80.0	68.3	MAKO
13	7	5	-7.04	1.03	.78	-.9	.61	.0	.49	.44	80.0	68.3	NDBO
1	6	5	-8.21	1.19	1.39	.8	1.32	.6	.17	.28	80.0	79.8	MKLO
14	6	5	-8.21	1.19	.61	-.6	.40	-.6	.39	.28	80.0	79.8	NTZO
15	6	5	-8.21	1.19	1.25	.6	1.00	.3	.22	.28	80.0	79.8	DLKO
MEAN	7.6	5.0	-5.85	1.27	.93	-.1	.78	.1			78.7	76.5	
P.SD	1.5	.0	2.96	.58	.35	.7	.40	.5			11.5	8.2	

Figure 5.12: Person measure order in the pre – TSPCK tools

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
2	16	5	5.64	1.33	.33	-.9	.20	-.4	.71	.51	100.0	85.1	ZOZO
4	16	5	5.64	1.33	.33	-.9	.20	-.4	.71	.51	100.0	85.1	FZWO
6	16	5	5.64	1.33	.33	-.9	.20	-.4	.71	.51	100.0	85.1	MKBO
3	14	5	1.05	1.43	.21	-.9	.13	-.6	.81	.60	100.0	88.2	NTUO
7	14	5	1.05	1.43	.21	-.9	.13	-.6	.81	.60	100.0	88.2	NQDO
5	13	5	-.58	1.14	.58	-.6	.38	-.2	.77	.64	80.0	77.5	MBLO
10	13	5	-.58	1.14	1.40	.8	1.41	.7	.45	.64	80.0	77.5	NDLO
13	13	5	-.58	1.14	2.21	1.7	2.25	1.2	.13	.64	40.0	77.5	NDBO
15	13	5	-.58	1.14	1.40	.8	1.41	.7	.45	.64	80.0	77.5	DLKO
1	12	5	-1.75	1.05	1.21	.5	1.02	.3	.48	.64	60.0	74.9	MKLO
8	12	5	-1.75	1.05	.38	-1.3	.32	-.9	.79	.64	100.0	74.9	JKWO
11	12	5	-1.75	1.05	.38	-1.3	.32	-.9	.79	.64	100.0	74.9	MAKO
9	11	5	-2.82	1.03	2.35	1.8	2.41	1.7	.55	.65	20.0	74.7	ARSO
12	11	5	-2.82	1.03	.94	.1	.76	-.1	.95	.65	60.0	74.7	MNYO
14	11	5	-2.82	1.03	1.26	.6	1.23	.5	.26	.65	60.0	74.7	NTZO
MEAN	13.1	5.0	.20	1.18	.90	-.1	.82	.0			78.7	79.4	
P.SD	1.7	.0	2.96	.15	.69	1.0	.74	.8			24.7	5.1	

Figure 5.13: Person measure order in the post – TSPCK tools

The Rasch person measures are interpreted in such a way that the more positive the Rasch measures are the higher the persons' ability. Additionally, the more these values move towards the negative values the lower the persons' ability and this was according to the design of the rubric which demonstrates the highest ability of the TSPCK test with level 4 and lowest ability with level 1 (limited TSPCK). In the pre-test scores, it is evident that at the beginning of the intervention the teachers' abilities to write the test were low, with only one teacher scoring with the group showing very high negative values to represent their different degrees of difficulty in the answering the tool. However, there was a shift in their post-intervention tests with the majority of teachers moving up closer to the positive values compared to their pre-test scores. These changes in the OFTs' results generated by the Rasch Analysis person measures attest to the improvement observed in the quality of the teachers' TSPCK written responses, indicating that teachers' knowledge of the TSPCK improved after the intervention. The mean value of teachers' Rasch measures increased from -5.85 to 0.20 to further prove that the teacher abilities improved post the intervention.

According to Boone, Staver, and Yale (2014) other important indices to measure when conducting quantitative analysis are in-fit statistics which are shown by IN and OUT z-standardized values denoted as IN and OUT ZSTD in the Figure 5.13. These values that measure the overall fit of the data to the model are important in determining the validity of the construct under investigation and therefore the tools used. For IN and OUT ZST values to indicate data that is conforming well with the model, these values should lie within the range of ± 2. Therefore, if the fit statistics are within the acceptable range then it means there is a fairly good alignment between person measures and item measures. This implies that both these measures are working in unison to bring valid measures of a single construct measured. The Rasch fit statistics for teachers above revealed good alignment of the data to the Rasch model as all teachers' both IN and OUT z-standardized indices of teachers were fitting with the acceptable range. The items of the tool were all working together to measure the validity of the TSPCK construct. The mean person measure in the pre-tests of the teachers was -5.85 while this measure increased to 0.20 in the post-tests.

- ***Item Statistics rank order***

In Table 5.4 above, raw score values from the rubric were converted into an equidistant scale which makes it possible to rank the abilities of persons participating in the test from persons with poor ability to those with good ability. In the same manner, as person measures reported above, higher values of item rank measures are interpreted as reflecting items that are more difficult which means only teachers with higher abilities are inclined to respond satisfactorily to these items. Figure 5.14 reflects item order of difficulty for each component of the TSPCK in both pre- and post-tests.

Person: REAL SEP.: 1.37 REL.: .65 ... Item: REAL SEP.: 1.99 REL.: .80

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
5	16	15	7.21	3.43	.03	-1.0	.01	-1.5	.84	.82	100.0	99.4	I0005
2	24	15	-1.35	.58	1.26	1.4	1.21	.5	.33	.55	60.0	69.1	I0002
3	24	15	-1.35	.58	1.10	.6	.94	.3	.71	.55	60.0	69.1	I0003
1	25	15	-1.69	.58	.77	-1.4	.63	.0	.42	.54	80.0	66.2	I0001
4	28	15	-2.83	.68	.82	-.4	.61	.2	.68	.55	86.7	80.6	I0004
MEAN	23.4	15.0	.00	1.17	.80	-.1	.68	-.1			77.3	76.9	
P.SD	4.0	.0	3.65	1.13	.42	1.0	.40	.7			15.5	12.3	

Figure 5.14: Item rank order for pre-tests in particulate nature of matter

In the table above, it is evident that the OFTs found Teaching Strategies and Curricular Saliency the most difficult in both pre- and post-tests. The Rasch measures for these items had the highest values at 7.21 and -1.35 in the pre-test respectively. Representations, Learner Prior Knowledge and What is difficult to teach were the easy items for the OFTs as these scored the lowest values at -2.83, -1.69 and -1.35 respectively in the pre-tests with the component of Representations being the easiest. While teaching strategies were ranked the most difficult in both TSPCK tests, there was a shift in the easiest ranked item whereby learner prior knowledge became the easiest in the post-test and representation followed after learner prior knowledge.

Person: REAL SEP.: 2.03 REL.: .80 ... Item: REAL SEP.: 2.69 REL.: .88

Item STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
5	32	15	3.28	.68	.98	.1	.88	.1	.79	.77	80.0	81.6	I0005
2	38	15	.53	.64	.72	-.7	.53	-.8	.66	.62	80.0	76.4	I0002
3	39	15	.13	.63	.79	-.5	.70	-.5	.58	.59	86.7	76.7	I0003
4	42	15	-1.04	.63	1.38	1.2	1.35	.7	.20	.53	60.0	76.2	I0004
1	46	15	-2.89	.80	1.08	.3	.66	.0	.88	.66	86.7	86.0	I0001
MEAN	39.4	15.0	.00	.67	.99	.1	.82	-.1			78.7	79.4	
P.SD	4.6	.0	2.02	.06	.24	.7	.29	.5			9.8	3.9	

Figure 5. 15: Item rank order for post-tests in particulate nature of matter

In the post-intervention tests, the Rasch item measures for these Teaching Strategies and Curricular Saliency were 2.07 and 1.43 respectively. The OFTs found it easier to engage with concepts of the particulate nature of matter through Learner Prior Knowledge, Representations and What is difficult to teach with Rasch measures of -2.01, -1.05 and -0.44 respectively.

According to Boone et al. (2014) the higher the values of the Rasch item, the more difficult they are. In this study, there is a noticeable trend in the item rank measures across the five TSPCK components. The Rasch values recorded in the pre-tests were higher than the values established post the intervention when comparing these for each item. This means that the OFTs experienced more difficulty in engaging concepts of the particulate nature of matter through the TSCPK components at the beginning of the intervention and this difficulty decreased post the intervention. These findings attest to the average raw score data on components of the TSPCK above which revealed that post the intervention, the OFTs' average score changed from 2 to 3.

This means their reasoning about the particulate nature of matter changed from using one component to formulate their responses into drawing interactively from another component to formulate their explanations. In tracking the interactions of TSPCK per component, it also revealed that this change was major in the components of

'*Representations', 'Learner Prior Knowledge 'and 'What is difficult to teach'. The Rasch measures have confirmed this change as these were* -2.83, -1.69 and -1.35. However, post the intervention the order changed with Learner Prior Knowledge being the easiest followed by Representations and What is difficult to teach before the intervention and were -2.89. <-1.04 <-1.05 and -0.44 after the intervention.

The raw score data has shown that for the component of Teaching strategies teacher scores changed from 1 to 2. For teaching strategies, the raw score data revealed that score changes from 1 to 2. This change was confirmed by Rasch measures with Rasch value change of 7.21 to 3.28 that implies that while in the pre-tests the majority of teacher scored 1 but, in the post-tests, most teachers scored between 2 and 3 that indicates that teachers improved after the intervention with higher ability than they had in the pre-tests.

- ***Summary Statistics***

The summary statistics for both pre-and post-instruments are given in Figure 5.16 which have been discussed in the sections above.

```
--------------------------------------------------------------------------------

     SUMMARY OF 15 MEASURED Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT          OUTFIT    |
|          SCORE      COUNT    MEASURE    S.E.      MNSQ   ZSTD    MNSQ   ZSTD  |
|-------------------------------------------------------------------------------|
| MEAN      11.9        5.0       -.98    1.02      1.00     .1     .92     .1  |
| P.SD       2.2         .0       2.35     .12       .52     .8     .52     .7  |
| S.SD       2.3         .0       2.43     .12       .54     .8     .54     .7  |
| MAX.      16.0        5.0       3.90    1.24      1.89    1.1    1.80    1.2  |
| MIN.       8.0        5.0      -4.61     .89       .19   -1.1     .16   -1.2  |
|-------------------------------------------------------------------------------|
| REAL RMSE   1.14 TRUE SD    2.05  SEPARATION  1.79  Person RELIABILITY  .76   |
|MODEL RMSE   1.03 TRUE SD    2.11  SEPARATION  2.05  Person RELIABILITY  .81   |
| S.E. OF Person MEAN = .63                                                     |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .74  SEM = 1.12


     SUMMARY OF 5 MEASURED Item
--------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT          OUTFIT    |
|          SCORE      COUNT    MEASURE    S.E.      MNSQ   ZSTD    MNSQ   ZSTD  |
|-------------------------------------------------------------------------------|
| MEAN      35.8       15.0        .00     .58      1.01     .1     .92    -.1  |
| P.SD       4.9         .0       1.64     .02       .36    1.1     .35     .9  |
| S.SD       5.5         .0       1.84     .02       .40    1.2     .39    1.0  |
| MAX.      43.0       15.0       1.92     .62      1.38    1.1    1.26     .7  |
| MIN.      30.0       15.0      -2.43     .56       .35   -2.0     .30   -1.8  |
|-------------------------------------------------------------------------------|
| REAL RMSE    .62 TRUE SD    1.52  SEPARATION  2.44  Item   RELIABILITY  .86   |
|MODEL RMSE    .58 TRUE SD    1.53  SEPARATION  2.64  Item   RELIABILITY  .87   |
| S.E. OF Item MEAN = .82                                                       |
--------------------------------------------------------------------------------
Item RAW SCORE-TO-MEASURE CORRELATION = -1.00
Global statistics: please see Table 44.
UMEAN=.0000 USCALE=1.0000


-------------------------------------------------------------------------------

     SUMMARY OF 15 MEASURED Person
-------------------------------------------------------------------------------
|          TOTAL                         MODEL         INFIT          OUTFIT    |
|          SCORE      COUNT    MEASURE    S.E.      MNSQ   ZSTD    MNSQ   ZSTD  |
|-------------------------------------------------------------------------------|
| MEAN      11.9        5.0       -.98    1.02      1.00     .1     .92     .1  |
| P.SD       2.2         .0       2.35     .12       .52     .8     .52     .7  |
| S.SD       2.3         .0       2.43     .12       .54     .8     .54     .7  |
| MAX.      16.0        5.0       3.90    1.24      1.89    1.1    1.80    1.2  |
| MIN.       8.0        5.0      -4.61     .89       .19   -1.1     .16   -1.2  |
|-------------------------------------------------------------------------------|
| REAL RMSE   1.14 TRUE SD    2.05  SEPARATION  1.79  Person RELIABILITY  .76   |
|MODEL RMSE   1.03 TRUE SD    2.11  SEPARATION  2.05  Person RELIABILITY  .81   |
| S.E. OF Person MEAN = .63                                                     |
-------------------------------------------------------------------------------
Person RAW SCORE-TO-MEASURE CORRELATION = .99
CRONBACH ALPHA (KR-20) Person RAW SCORE "TEST" RELIABILITY = .74  SEM = 1.12
```

SUMMARY OF 5 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	35.8	15.0	.00	.58	1.01	.1	.92	-.1
P.SD	4.9	.0	1.64	.02	.36	1.1	.35	.9
S.SD	5.5	.0	1.84	.02	.40	1.2	.39	1.0
MAX.	43.0	15.0	1.92	.62	1.38	1.1	1.26	.7
MIN.	30.0	15.0	-2.43	.56	.35	-2.0	.30	-1.8

REAL RMSE .62 TRUE SD 1.52 SEPARATION 2.44 Item RELIABILITY .86

MODEL RMSE .58 TRUE SD 1.53 SEPARATION 2.64 Item RELIABILITY .87

S.E. OF Item MEAN = .82

Item RAW SCORE-TO-MEASURE CORRELATION = -1.00

Global statistics: please see Table 44.

UMEAN=.0000 USCALE=1.0000

Figure 5.16: Reliability indices for pre and post TSPCK tools

The item reliability was consistent as it was 0.72 in pre-tests and 0.86 in the post-tests that both fall within the acceptable Cronbach 0.7 value. The person reliability was 0.76 in both pre- and post-tests which is 0.5 and therefore lies within the acceptable range of 0 to 1.

5.4. Conclusion

The analysis determined possible shifts in the quality of the TSPCK of a planned teaching context as a direct result of an explicit intervention. In a TSPCK intervention designed for this study, the analysis above produced two major findings.

The first finding revealed a positive 1-category shift towards a higher quality of the TSPCK across all the OFTs. The second finding derived from individual average scores, indicated a 2-category shift towards a higher quality of the TSPCK for majority of the OFTS. These findings were an indication of a positive shift in the quality of TSPCK interactions of the OFTs in their post-tests as compared to their pre-tests, which has come about because of the intervention carried out for this study.

On the other hand, the quantitative analysis and results presented in this chapter also indicate an overall improvement of teachers' TSPCK in the particulate nature of matter when exposed to the TSPCK-based intervention. In the above discussions, both the rubric and the statistical model together with the qualitative evidence from teacher questionnaires were used to establish and validate the quantitative analysis through qualitative developments which resulted in the improvements depicted through quantitative data analysis.

The implicit developments in engaging the TSPCK components interactively were presented through qualitative evidence to shed light on learning channels which paved the way to the improvements in the quality of TSPCK. It was specifically within the components of '*Learner Prior Knowledge'*, '*Representations'* and '*What is difficult to teach'* that teachers started showing more interactions of components in formulating their responses making these three components the largest points of improvement.

It is argued that teachers who are teaching topics out of the field of their training tend to have weak content knowledge with a superficial approach towards their content knowledge. The positive shifts in the OFTs TSPCK which were the basis of this study warrants further investigation as the TSPCK intervention is the only factor which made an impact on teachers' knowledge gains in the particulate nature of matter. The findings were reported in the following chapter.

CHAPTER 6

IMPACT OF AN EXPLICIT INTERVENTION ON CONTENT KNOWLEDGE IN THE TOPIC OF PARTICULATE NATURE OF MATTER

Literature has reported on the situation of out-of-field teaching as one that is indicative of teacher's inadequate subject matter knowledge. In the previous chapter, the impact of the intervention on the quality of the TSPCK of the OFTs was analysed and reported. In this chapter, the focus is on the impact of the TSPCK based intervention in improving content knowledge of the *OFTs. To establish the impact of the intervention on their SMK, a set of pre and post CK tests were analysed. The topic of the intervention was the particulate nature of matter and thus, the measured topic in the tests.*

6.1. Introduction

In science education, it is argued that TSPCK like PCK is the transformation of content knowledge into various forms, that learners can easily understand. This implies that content knowledge is pre-requisite to the development of PCK in a specific topic. In this study, the aim was to investigate the development of TSPCK in the OFTs. However, it is argued that it is not only the transformation of Content Knowledge of specific topics (TSPCK) which is a challenge to the OFTs but also weaker content knowledge in the topics which they teach out-of-field. Thus, in this study, the investigation of the development of the TSPCK through TSPCK based intervention included evaluation of the impact of the intervention on the development of content knowledge of the OFTs in the particulate nature of matter. The research question that this chapter seeks to address is:

(i) *what is the impact of the intervention on OFTs' content knowledge in the topic of the particulate nature of matter?*

In responding to this research question, data gathered through the CK tests and Core entries by teacher groups during the face-to-face PDI were used. The raw score data from the CK tool was analyzed both qualitatively and quantitatively. The OFTs wrote CK tests on the first and last day of the intervention, which took them about 60 minutes to complete. A full copy of the tool is provided in the list of appendices as Appendix 3. As it was the case with the TSPCK, the shifts in the OFTs' conceptual understanding of the particulate nature of matter was measured using pre and post-intervention content knowledge (CK) tools. The items of the CK tests were designed and validated in a study by Pitjeng-Mosabala and Rollnick (2018), thus, considered piloted and validated. The items from the CK test which did not fit the Junior Secondary syllabus were replaced with items from a study by Brook, Briggs, and Driver (1984). The study by Brook et al. (1984) reports on widely and intensively well-researched items in the particulate nature of matter; thus, the items extracted from this book were also considered piloted and validated. The details of the adaptation and editing of the CK instrument were given in chapter 3. To analyze data for this chapter, the two sets of pre and post-intervention tests were scored as if it were a conventional test using a memorandum of correct answers. Also, the memorandum came from a study by Pitjeng-Mosabala and Rollnick (2018) that was constructed with a reference team of experienced science teachers thus considered valid.

6.2. Quantitative analysis for CK tests

To analyze the entire pre and post interventions tests of the OFTs, the researcher marked the tests using a marking memorandum. Pseudonyms were used in reporting their scores. For peer validation of the scores, the scored tests were given to a fellow masters PCK research student who was familiar and experienced in working with the construct of TSPCK. As in the case of the TSPCK instruments, the inter-rater reliability was established using the same method and the inter-rater reliability achieved was 0.92. Similarly, to the TSPCK tests, where there was disagreement, raters who were myself and the peer validator discussed the differing scores using the memorandum to support our differing scores. The authors' role was to oversee and decide the final score in a case where consensus could not be reached.

- ***Normalised Gain***

The total mark of the entire CK test was 79 and was converted into the percentage for ease of analysis. The mark allocation for Question 1 was 5 marks (1 mark for each of the five terms that were expected), 48 marks for Question 2 with a mark awarded for each correct diagram given, all possible correct answers are given in Appendix 6. There were 6 marks allocated for question 3 (each drawing was awarded 2 marks), 4 marks for question 4 (1 mark for each question) and 16 marks for question 5 (5a and 5b were awarded 2 marks and 5c, 5d and 5e were awarded 4 marks for each explanation). The percentage scores of individual teachers were used to analyse individual Normalized gain on concepts of the particulate nature of matter. In Table 6.1 are percentage scores from the OFTs' pre- and post-intervention, the CK test and the calculated Normalized gains measures.

Table 6.1: Overall teacher scores in pre and post-tests of the CK tool

Teacher	Pre-test score %	Post-test score %	Normalized Gain
1. Amanda	29.1	50.6	0.3
2. Harriet	36.7	74.7	0.6
3. Merriam	73.4	82.3	0.3
4. Antana	29.1	59.5	0.4
5. Sophie	31.6	58.3	0.4
6. Noreen	25.3	73.4	0.6
7. Mary	40.5	57.0	0.3
8. Nicky	34.2	68.4	0.5
9. Nosipho	41.7	84.8	0.7
10. Noxy	37.9	55.7	0.3
11. Zukie	29.1	50.6	0.3
12. Fiona	29.1	55.7	0.4
13. Thabo	35.4	54.4	0.3
14. Litha	44.3	64.5	0.4
15. Andile	48.10	64.5	0.3
Average	**37.8**	**63.5**	**0.4**

In this study, Normalized gain (G) is defined as a measure of the change in score divided by the Maximum possible increase given by the formula:

Normalized gain is a measure of the fraction of the concepts learned that was not already known at the beginning of the course (Coletta & Phillips, 2007) which was an intervention in the case of this study. Thus, in this chapter to measure the learning of the particulate nature of matter, concepts independent of the teachers' initial understanding, used Normalised gain analysis. The CK tools were used to measure the understanding of the particulate nature of matter concepts before and after exposure to a signature intervention with an explicit focus on the TSPCK. According to Coletta and Phillips (2007), the G values above 0.6 belong on the upper quartile of Lawsons' score and G values below 0.3 fell in the lower quartile. In this study, G values for the out-of-field teachers were in the range of 0.3 – 0.6 which means the fraction of the concepts learned that was not already known at the beginning of the intervention were relatively higher effective gains of understanding in the concepts of the particulate nature of matter.

In Table 6.1 above, the raw scores have revealed a general improvement across the entire cohort. In the pre-test scores, the OFTs achieved an average of 37.8 % while in the post-tests OFTs achieved an average score of 63.5 % resulting in an average normalised gain of 0.4. In the pre-tests, the majority of OFTs could not achieve 50% in the CK test but this improved in the post-tests, where majority of OFTs were able to achieve scores above 50 %.

6.3.1 Rasch statistical Model

The generated raw scores were also subjected into Rasch Analysis for validity and reliability. This underlying assumption of unidimensional in Rasch analysis helped in verifying whether the concepts of the particulate nature of matter used by the school curriculum at Junior Secondary level were all working together to measure the CK of the particulate nature of matter of the teachers and thereby validating the person reliability and item reliability through fit statistics.

- ***Person Fit Statistics***

This model was used in this study to produce a score which summarizes a persons' ability on a variable, which was the CK in the particulate nature of matter. The analysis yields informative tables that are on the same metric in which both person proficiencies and item difficulties can be compared. Thus, the raw score data (see Table 6.1.) which was generated from the discussions above was then subjected to Rasch statistical model for quantitative analysis. Figure 6.1 represents person statistics of the teachers before their exposure to the signature intervention.

Person: REAL SEP.: .58 REL.: .25 ... Item: REAL SEP.: 3.05 REL.: .90

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
3	18	5	1.16	.46	2.19	1.6	3.14	2.2	[illegible]	.65	20.0	47.4	NTT
9	16	5	.76	.44	.50	-.8	.52	-.7	.95	.70	40.0	31.0	ARS
13	16	5	.76	.44	1.23	.6	1.43	.8	.53	.70	.0	31.0	NDB
1	15	5	.57	.44	.41	-1.1	.42	-1.0	.89	.71	60.0	31.5	MKL
5	15	5	.57	.44	.41	-1.1	.42	-1.0	.89	.71	60.0	31.5	MBL
10	15	5	.57	.44	.98	.2	1.12	.4	.61	.71	20.0	31.5	NDN
14	15	5	.57	.44	.24	-1.7	.27	-1.5	.97	.71	60.0	31.5	NTZ
15	13	5	.19	.44	.96	.1	.99	.2	.70	.72	20.0	33.3	DLK
2	11	5	-.19	.44	3.38	2.7	3.21	2.5	[illegible]	.71	.0	38.4	ZOZ
6	11	5	-.19	.44	1.23	.6	1.08	.3	.87	.71	60.0	38.4	MKB
7	10	5	-.39	.45	.51	-.8	.49	-.8	.75	.70	20.0	39.6	NQD
8	10	5	-.39	.45	.63	-.5	.72	-.3	.84	.70	20.0	39.6	JKW
12	10	5	-.39	.45	.53	-.7	.56	-.6	.98	.70	20.0	39.6	MNY
11	9	5	-.59	.46	.57	-.6	.68	-.3	.60	.69	60.0	43.4	MKL
4	8	5	-.81	.47	.47	-.8	.71	-.3	.77	.67	60.0	41.7	SKH
MEAN	12.8	5.0	.15	.44	.95	-.2	1.05	.0			34.7	36.6	
P.SD	3.0	.0	.58	.01	.81	1.1	.89	1.1			22.5	5.1	

Figure 6.1: Person fit statistics for CK tests before the intervention

In Figure 6.1 above, two attributes were considered and these were person measures and fit statistics. The teachers with high ability were represented by increasing positive values of Rasch measurements and those with poor ability were represented by increasing negative Rasch values. In the pre-tests of the out-of-field teachers' CK tests, one teacher had the highest ability of 1.16, followed by 2 teachers who had Rasch measures of 0.76, 4 teachers with Rasch measures of 0.57 and 1 teacher with 0.19. The rest of the teachers had different negative Rasch measure values which represented various individual level of poor person ability. The validity of the instruments was established through the use of z-standardised measures. These values produce infit z-standardised numbers and outfit-standardised values which are called ‘fit statistics’. These values are of paramount importance in determining validity construct of instruments. The accepted Z-STD values are within the range of +2 and -2. In Table 6.2, these standards were used to establish whether both person and item measures were working together to measure a single construct and thus establishing construct validity. In the pre-tests teacher Merriam and Harriet were not fitting with the acceptable range and thus were misfits.

Teacher Merriam was teaching in a different context compared to other teachers as she was firstly teaching in a high school while other teachers were teaching at Junior Secondary schools which had an intake of from Grade R to Grade 9. Teacher Merriam also mentioned that she was also teaching Grade 10 Physical Science and that might explain her high level of content knowledge.

On the other hand, while teacher Harriet was also an out of field science teacher, she had more experience of teaching Natural Sciences as she had 4 years of teaching compared to the rest of the cohort who ranged between 1-and 2- years teaching experience in Junior Secondary level.

In the post-intervention tests, all teachers were lying within the expected range of fit statistics. In Figure 6.2 are person fit statistics after exposure to the intervention.

Person: REAL SEP.: 1.19 REL.: .59 ... Item: REAL SEP.: 3.54 REL.: .93

Person STATISTICS: MEASURE ORDER

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PTMEASUR-AL CORR.	PTMEASUR-AL EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Person
3	24	5	4.98	1.10	1.06	.4	.58	.1	.40	.44	60.0	80.2	NTT
2	22	5	3.35	.79	.90	.1	.59	-.1	.75	.67	80.0	66.6	ZOZ
9	22	5	3.35	.79	1.01	.3	.71	.1	.69	.67	40.0	66.6	ARS
4	19	5	1.84	.63	.50	-.6	.51	-.6	.89	.74	80.0	59.4	SKH
5	19	5	1.84	.63	.37	-.9	.60	-.4	.82	.74	80.0	59.4	MBL
15	19	5	1.84	.63	1.44	.8	1.09	.4	.86	.74	60.0	59.4	DLK
6	18	5	1.47	.58	2.27	1.6	2.18	1.6	-.37	.74	.0	47.2	MKB
8	18	5	1.47	.58	1.11	.4	1.34	.7	.62	.74	60.0	47.2	JKW
10	18	5	1.47	.58	.83	.0	.85	.0	.86	.74	20.0	47.2	NDN
12	18	5	1.47	.58	.79	-.1	.63	-.4	.95	.74	60.0	47.2	MNY
14	18	5	1.47	.58	.79	-.1	.63	-.4	.95	.74	60.0	47.2	NTZ
1	17	5	1.16	.55	1.49	.9	1.11	.4	.92	.75	60.0	45.1	MKL
13	17	5	1.16	.55	.51	-.7	.63	-.5	.88	.75	40.0	45.1	NDB
7	16	5	.87	.53	1.00	.2	.92	.1	.64	.76	60.0	44.1	NQD
11	16	5	.87	.53	1.12	.4	1.05	.3	.57	.76	20.0	44.1	MKL
MEAN	18.7	5.0	1.91	.64	1.01	.2	.89	.1			52.0	53.7	
P.SD	2.2	.0	1.09	.15	.45	.6	.42	.5			22.9	10.6	

Figure 6.2: Person fit statistics for CK tests after intervention

The results of the person statistics in the post-test scores were evidence that the instrument was measuring a single proposed construct which was the CK of teachers in the particulate nature of matter. The columns of post person measures of fit statistics have shown an improvement which is given in the fourth column of Figure 6.2.

In the post-tests, all teachers had a variety of positive Rasch measures. Teacher Merriam had highest Rasch measure of 4.98 while teacher Mary and Zukie had the lowest measures of 0.87 each and the rest of teachers performed in between. This discovery by Rasch method where the entire cohort produced positive Rasch measures in the post-intervention tests was an indication that there was an improvement in teachers' conceptual understanding in the particulate nature of matter. These findings validated findings in Table 6.1 above which indicated that teachers' overall score achievement of 37.8% in the pre-tests to 63.5% post the intervention resulting in the normalized gain of 0.4. This also meant almost the entire cohort could not achieve above 50 % in the pre-tests. This also confirms the general knowledge that out-of-field teachers tend to have low levels of content knowledge.

- ***Summary of Statistics***

The Rasch model was used to establish person and item reliability. The reliability measures determined the internal consistency of the measurement by generating separate reliability values for persons and items. In Figure 6.3, person and item reliability values of the CK test before the intervention are presented.

SUMMARY OF 15 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	12.8	5.0	.15	.44	.95	-.2	1.05	.0
P.SD	3.0	.0	.58	.01	.81	1.1	.89	1.1
S.SD	3.1	.0	.60	.01	.84	1.1	.92	1.1
MAX.	18.0	5.0	1.16	.47	3.38	2.7	3.21	2.5
MIN.	8.0	5.0	-.81	.44	.24	-1.7	.27	-1.5

REAL RMSE	.50	TRUE SD	.29	SEPARATION	.58	Person RELIABILITY	.25
MODEL RMSE	.45	TRUE SD	.37	SEPARATION	.84	Person RELIABILITY	.41

S.E. OF Person MEAN = .16

SUMMARY OF 5 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	38.4	15.0	.00	.26	.95	-.2	1.05	.1
P.SD	14.9	.0	.88	.01	.42	1.2	.51	1.3
S.SD	16.6	.0	.99	.01	.47	1.3	.57	1.4
MAX.	58.0	15.0	.99	.27	1.73	1.9	2.01	2.3
MIN.	22.0	15.0	-1.17	.24	.53	-1.6	.53	-1.6

REAL RMSE	.28	TRUE SD	.84	SEPARATION	3.05	Item RELIABILITY	.90
MODEL RMSE	.26	TRUE SD	.84	SEPARATION	3.27	Item RELIABILITY	.91

S.E. OF Item MEAN = .44

Figure 6.3: Summary statistics for Reliability indices for pre-intervention CK tests

The item-reliability measures were 0.9 which were both above the accepted 0.7 Cronbach's Alpha which measures the internal consistency of items. In the pre-tests, the person reliability was below the accepted probability of 0.5 which was 0.29. As alluded to in Chapter 2, the low person reliability values might have been caused by the fact that the sample of this study was out-of-field teachers and therefore their proficiencies and abilities to answer the questions on the items were almost the same. Low Person reliability measures are an indication that there was not sufficient spread of the persons' ability to respond in the CK tool and therefore more participants would need to be added to enhance the person reliability measures. In Figure 6.4 are person fit statistics of the cohort after exposure to the intervention.

SUMMARY OF 15 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	18.7	5.0	1.91	.64	1.01	.2	.89	.1
P.SD	2.2	.0	1.09	.15	.45	.6	.42	.5
S.SD	2.3	.0	1.13	.15	.47	.6	.43	.6
MAX.	24.0	5.0	4.98	1.10	2.27	1.6	2.18	1.6
MIN.	16.0	5.0	.87	.53	.37	-.9	.51	-.6

REAL RMSE .70 TRUE SD .84 SEPARATION 1.19 Person RELIABILITY .59
MODEL RMSE .66 TRUE SD .87 SEPARATION 1.32 Person RELIABILITY .64
S.E. OF Person MEAN = .29

SUMMARY OF 5 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	56.2	15.0	.00	.38	.97	-.1	.89	-.1
P.SD	11.9	.0	1.53	.08	.43	1.2	.35	.8
S.SD	13.3	.0	1.71	.08	.48	1.3	.39	.9
MAX.	70.0	15.0	2.12	.49	1.61	1.6	1.32	.8
MIN.	38.0	15.0	-1.97	.27	.49	-1.6	.48	-1.4

REAL RMSE .42 TRUE SD 1.47 SEPARATION 3.54 Item RELIABILITY .93
MODEL RMSE .38 TRUE SD 1.48 SEPARATION 3.86 Item RELIABILITY .94
S.E. OF Item MEAN = .77

Figure 6.4: Summary statistics for Reliability indices for post-intervention CK tests

The item reliability in the post-test scores was 0.93. Additionally, the person reliability improved significantly in the post-intervention tests as it was 0.59. This improved person reliability measure after the intervention. The fact that the problem was not on the instruments used in this study was further confirmed by the internal consistency of item reliability of 0.90 in the pre-tests and 0.93 in the post-tests which implies that the items were consistent in measuring CK of particulate nature of matter but the problem was teachers of this sample.

This was further proved by the improvement of both person and item reliability after both tests were subjected to stacked Rasch Analysis. In Figure 6.5 are summary statistics of stacked analysis

SUMMARY OF 30 MEASURED Person

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	15.8	5.0	.85	.52	.97	.0	1.00	.0
P.SD	4.0	.0	1.05	.10	.76	1.0	.84	1.0
S.SD	4.0	.0	1.07	.11	.77	1.0	.85	1.0
MAX.	24.0	5.0	3.86	1.02	4.14	3.2	4.29	3.2
MIN.	8.0	5.0	-1.01	.47	.22	-1.8	.27	-1.6

REAL RMSE .58 TRUE SD .87 SEPARATION 1.50 Person RELIABILITY .69
MODEL RMSE .53 TRUE SD .90 SEPARATION 1.70 Person RELIABILITY .74
S.E. OF Person MEAN = .19

SUMMARY OF 5 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	94.6	30.0	.00	.21	1.02	-.1	1.00	-.2
P.SD	26.4	.0	1.07	.02	.50	1.7	.46	1.5
S.SD	29.5	.0	1.20	.03	.56	1.9	.52	1.7
MAX.	128.0	30.0	1.35	.25	1.93	2.7	1.80	2.1
MIN.	60.0	30.0	-1.43	.19	.51	-2.3	.49	-2.4

REAL RMSE .24 TRUE SD 1.05 SEPARATION 4.45 Item RELIABILITY .95
MODEL RMSE .21 TRUE SD 1.05 SEPARATION 4.97 Item RELIABILITY .96
S.E. OF Item MEAN = .54

Figure 6. 5: Summary statistics for reliability indices for post-intervention CK tests

When the pre and post results were then subjected to stacked Rasch analysis to determine whether the person-reliability measures would improve if more teachers were added post the intervention not having same abilities. The Rasch analysis generated both person and item reliability above accepted indices thus improving the person reliability to 0.69 and item reliability was 0.95.

Like the TSPCK tests, the CK raw scores were first converted into equal-interval data through the Rasch model to increase critical objectivity of the results. The Rasch person measures were then used to conduct a sign test and subjected to a non-parametric Wilcoxon Paired Signed rank to calculate significance difference in the achievement scores. The significance level for this paired sign tests was conducted at level α = 0.05. The paired sign test used above establishes the difference when p values are less than the standard significance level of the sign tests. This implied that the two-sample means are significantly different, but if the p-value is above the standard significance level that would mean the two tests are the same. It was through this analysis that the overall shift of the OFTs achievement scores was established. The results of this analysis are provided in Figure 6.6.

Pre-test	Post-tests	Diff= (Yi-Xi)	Abs(Diff)	Rank	Signed Rank	T	120
1,16	4,98	3,82	3,82	15,00	15	n=	15
0,76	3,35	2,59	2,59	12,00	12	σ{T}	35,2136
0,76	1,16	0,4	0,4	1,00	1	α	0,05
0,57	1,84	1,27	1,27	6,00	6	Action(L)	-69,0
0,57	1,47	0,9	0,9	3,50	3,5	Action(U)	69,0
0,57	1,47	0,9	0,9	3,50	3,5	z	3,4
0,57	1,16	0,59	0,59	2,00	2	Reject Null at 0,05	
0,19	1,84	1,65	1,65	8,00	8	*p*	0,001
-0,19	1,47	1,66	1,66	9,00	9		
-0,19	3,35	3,54	3,54	14,00	14		
-0,39	0,87	1,26	1,26	5,00	5		
-0,39	1,47	1,86	1,86	10,50	10,5		
-0,39	1,47	1,86	1,86	10,50	10,5		
-0,59	0,87	1,46	1,46	7,00	7		
-0,81	1,84	2,65	2,65	13,00	13		
		#N/A			#N/A		

Figure 6. 6: Significance difference using Wilcoxon signed-rank test

As indicated by Figure 6.2 above, the analysis for pre- and post-intervention the CK scores were conducted at a significance level of α = 0.05. The estimated outcome for p-value for this run was 0.001 which is far less than 0.05 significance level. This is evidence that there is a significant difference between the means of the pre and post CK tests. This implies that the OFTs experienced a substantial gain in knowledge of understanding of the CK concepts in the particulate nature of matter.

6.3. Qualitative analysis for CK tests

It is important to note that there was no point in this study where an intervention was conducted based on the pure CK concepts in the particulate nature of matter. As explained in chapter 4, that the intervention focused on the construct of TSPCK as a means for the transformation of content knowledge into ways that student can understand. In this chapter, the evidence is presented on the shifts in understanding of CK concepts in the particulate nature of matter as a result of exposure to an explicit intervention of TSPCK.

The improvement seen in the CK scores discussed in this chapter was linked to the TSPCK-based intervention specifically those concepts, which were discussed through the TSPCK components during the intervention. The establishment of this link is of paramount importance for correlating the impact of the intervention in the conceptual understanding of the CK of the particulate nature of matter. Table 6.2 illustrated correlation between CK concepts that were covered in the CK tool and CK concepts that were discussed from the perspective of TSPCK components during the intervention.

Table 6.2: Correlation between CK concepts and CK concepts discussed from the perspective of TSPCK components during the intervention

Item no.	CK concepts covered	Average mean score (Pre) in %	Average mean score (Post) in %	Extent of shift (%)	TSPCK components	What was done in the intervention
1a-e, 4a	Classification of pure substances, mixtures, atoms and molecules	78	94	16	Learner Prior Knowledge including Misconceptions	Discussing teacher understanding of Learner Misconceptions through a designed prompting questions using the following CK concepts: - Matter is made up of small bits called particles - There are different types of small bits of a substance with different arrangements - Particle behavior during phase change
2a-h	Identifying different particle representations for different molecules, pure substances and mixtures.	33.5	61.8	28.3	Representations	Introducing Representations through the following intervention activities: - Identification of both micro and macroscopic representations of particulate nature of matter
3	Drawing microscopic representations of a molecule in its three phases of matter	68.3	91.6	23.3	Representations	Introducing Representations through the following intervention activities: - Microscopic representations of different types of particles in different phases

4b-d	Confirmation of facts about molecules of a substance	42.5	72.5	30	Curricular Saliency	Tabulating teacher understanding on Curricular Saliency through designed prompting questions through the following big ideas: Big ideas: - Particles are in constant motion - There is empty space between particles - There are different types of small bits of substance with different arrangements - Particles of different substances are different with different
5a	Atomic structure	55	90	35	Curricular saliency	Tabulating teacher understanding on Curricular Saliency through designed prompting questions using the big idea: Matter is made up of small bits that are called particles
5b&e	Particulate nature of matter at gaseous phase	31	54	23	Teaching Strategies	- Highlighting the manner in which misconceptions of the following concepts can be used to devise conceptual teaching strategies: Particulate nature of matter at gaseous phase (expansion, contraction, pressure,
5c	Effect of Temperature on particles	18.3	37	18	Teaching Strategies	
5d	Expansion and Contraction	15	38	23	Teaching Strategies	

						arrangement of gas particles)

Table 6.3 is a summary of the OFTs average performance in their pre- and post-intervention CK tests. The difference in shifts was given in column five of Table 6.3. In the second column of the Table 6.3, concepts that were asked in the CK test were provided. The improvement in the CK understanding of this test was linked with the specific concepts discussed from the TSPCK components perspective during the intervention. The discussions about the CK concepts during the intervention were never discussed as stand-alone concepts but from the TSPCK components perspective. Thus, in this section, the improvement seen for each item of the CK test is linked to the TSPCK intervention. The CK concepts which were discussed from the TSPCK component perspective fosters a better understanding of the concepts. The details of this link were discussed through qualitative data analysis in the next section, using selected specific concepts from the intervention.

6.3.1 Evidence of knowledge gain in CK through discussing from Learner Prior Knowledge perspective

As given in Table 6.3 above, examples of concepts that were used to discuss the knowledge component of learner prior knowledge were based on widely reported learner misconceptions. Specifically, the focus was bringing into discussion learner misconceptions about the big idea that states "*there are different types of small bits of a substance with different arrangements*".

For example, one of the most common misconceptions reported in literature includes the use of the term "molecule" and "atom" interchangeably. The scientific principle which forms the basis of this Big idea lies in the understanding that there are two types of particles and these are atoms and molecules. The concept then builds up into elements, compounds and mixtures. This knowledge helps us understand the reason behind having a limited number of elements whilst there are many different kinds of compounds. During the intervention, discussions around this concept and its sub-concepts were brought into the discussion through the activity shown in Figure 6.7:

Example 2
Teacher: What happens to water molecules when water boils?
Student: When water boils, hydrogen and oxygen molecules will separate.
Task 2
- Identify student misconception in the learner response above?
- What is the appropriate response here?

Figure 6.7: Extract of TSPCK activity during the intervention

The main purpose of the activity above was to drive discussions that foster a conceptual understanding about the difference between atom and molecule and then elements, compounds and mixtures. During the intervention the majority of the OFTs struggled to spot the difference between an “atom” and a “molecule”. For example, when the OFTs were asked to discuss the activity given in Figure 6.1 above in their designated groups during the intervention, two teacher responses were chosen as suitable responses which would be able to facilitate discussions that seek to address common learner misconceptions around these concepts. Teacher Antana and Noreen responded as given by Figure 6.8 in corresponding to the above workshop activity:

Teacher Antana	Teacher Noreen
Since water is made up of oxygen and hydrogen bubbles are a result of the collision between hydrogen atoms and oxygen atoms because of the increase in temperature	I can say yes water is made up of hydrogen and oxygen but it doesn’t break

Figure 6.8: Teacher responses in a workshop activity early in the intervention

From the teacher responses above, teacher Antana stated that ‘water is made up of oxygen and hydrogen’. These two responses were used to facilitate the whole group discussion with the entire cohort. The first response was then noted down on the blackboard and the entire cohort was asked if they thought the response given by teacher Antana was correct. While the activities of the intervention were meant to facilitate discussions about learner misconceptions which learners had when teaching the concept ‘*there are different types of small bits of a substance with different arrangements*’, the CK of the OFTs was also exposed. The exposure of teachers’ understanding of these CK concepts resulted in discussions about their correct understanding and accurate definitions thus conceptual understanding.

For example, the OFTs were allowed to express their views and consolidated the discussion by pointing out that the response by teacher Antana that states 'water is made up of oxygen and hydrogen' while this was correct, could be read as if though the smallest bit of a single water molecule is made up of separate hydrogen and oxygen atoms which is wrong and could lead to misconceptions.

The consolidation session was closed by stating to the entire group when a hydrogen *atom* and an oxygen *atom* form a bond they form a hydrogen oxide *molecule* and that it is only hydrogen oxide (water) molecules that make up water and not hydrogen and oxygen atoms. The emphasis of this statement was on the fact that an atom is the smallest particle of a chemical element that can exist while a molecule is when two or more atoms form a chemical bond with each other whether these atoms are the same or not.

Teacher Noreen's response was also noted down on a blackboard and similar discussions were done. This response was discussed as that which meant that the teacher was aware that a single molecule of water substance should be the smallest building block which should be unbreakable; however, the terminology she is using had other implications which could lead to the wrong information about the concept. Teacher Noreen stated that water is made up of hydrogen and oxygen instead of saying water is made up of hydrogen oxide or water molecules because it is only hydrogen oxide molecules that are made of these two single atoms. This led to discussions about the correct conceptual understanding of how elements differed from compounds.

Similarly, Question 1 and 4a of the CK test were probing for the same conceptual understanding, as it required the OFTs to identify scientific definitions for atom, molecule, compound, element and mixtures of elements and compounds. The teacher problems of the concepts were also noted on their CK tests prior to the intervention. Figure 6.9 is the first question of the CK tool.

1. Give one word or term for each of the following description.

(a) A substance that is made of only one kind of atom.

(b) A substance made of two or more atoms of different elements chemically bonded.

(c) A smallest particle of an element that still retains the chemical properties of that element.

(d) A particle that consists of two or more atoms bonded together.

(e) A substance that consists of different substances that are not chemically bonded to each other and still retai their original properties.

Figure 6.9: Extract of question 1 of the CK test

The first item of the CK test was probing teachers' understanding of different types of small bits in a substance. Table 6.4 illustrated teacher scores in the first question of the CK tool. In Table 6.4 were the results of the OFTs' understanding before and after the intervention. A correct response was denoted by a ✓ while an incorrect response was denoted by X. In a case where teachers omitted the question or left the question blank, zero was used to represent no response.

Table 6.3: Overall teacher scores on in question 1 of the CK tool

Teacher	**Question 1a**		**Question 1b**		**Question 1c**		**Question 1d**		**Question 1e**		**Total No. of Correct Responses**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
1.Mary	✓	✓	X	✓	✓	✓	✓	X	✓	✓	4	4
2. Sophie	✓	✓	✓	X	✓	✓	X	✓	✓	✓	4	4
3. Antana	✓	✓	X	✓	✓	✓	✓	✓	X	✓	3	5
4. Harriet	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	5	5
5. Amanda	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	4	5
6. Merriam	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	5	5
7. Nicky	✓	✓	✓	✓	✓	✓	X	✓	X	✓	3	5
8. Nosipho	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	5	5
9. Fiona	✓	✓	✓	✓	X	✓	X	✓	✓	✓	3	5
10. Zukie	✓	✓	✓	✓	X	✓	X	X	X	✓	2	4
11. Thabo	✓	✓	✓	✓	✓	✓	X	X	X	✓	3	4
12. Noxy	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	3	5
13. Noreen	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	4	5
14. Andile	✓	✓	✓	✓	✓	✓	X	✓	✓	✓	4	5
15. Thabo	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	5	5
Total No. of teachers with incorrect responses	0	0	2	1	2	0	9	3	4	0		

In Question 1a, 15 out of 15 teachers were able to give the correct word, which was 'Element' in both pre and post-tests. In Question 1b only two teachers could not give the correct word, which meant 13 out of 15 of the OFTs were able to identify the definition for a compound in the pre-tests but in the post-intervention test, 14 out of 15 of the OFTs were able to give the correct answer. In Question 1c, 13 out of 15 teachers gave a correct answer and post the intervention all 15 teachers gave the correct responses.

In question 1d, the OFTs performed least well for question 1d as the majority of the OFTs were confused in understanding the definition of a molecule. Some OFTs left this question blank, some gave "compound". Only 6 out of 15 teachers gave correct responses while 9 out of 15 gave incorrect responses. In Question 1e, 11 out 15 teachers were able to give the correct response for this item while three teachers omitted this question and 1 teacher gave 'compound' as an answer.

However, after the intervention all 15 teachers were able to identify the given definition of the 'Atom'. Post-intervention tests revealed that by the end of this intervention all 15 teachers were able to identify 'mixture' as the correct word which matches the definition provided in sub-question 1e.

Question 4a is another example of a question corresponding to concepts used in discussing learner prior knowledge through the Big Idea: "*there are different types of small bits of a substance with different arrangements*". Table 6.5 shows the CK scores for both pre- and post-test scores for question 4a, where a teacher was either correct or incorrect.

Table 6.4: Overall teacher scores in question 4a of the CK tool

Teacher	Question 4a - True	
	Pre	Post
Amanda	✓	✓
Merriam	✓	✓
Nicky	0	✓
Thabo	✓	✓
Mary	0	✓
Harriet	0	✓
Sophie	✓	✓
Antana	✓	x
Nosipho	✓	✓
Fiona	x	✓
Zukie	x	✓
Noxy	✓	x
Noreen	x	✓
Litha	✓	✓
Andile	✓	x
Total No. of teachers with incorrect &/or blank response	6	3

It is evident from the Table 6.5 above that in the post-intervention tests, more teachers were able to identify the scientific facts as true and false appropriately and there were fewer numbers of omitted questions as opposed to pre-intervention tests.

For example, in 4a, teachers were expected to state whether it was true or false that: '*All molecules of a given substance are identical'.* Only 9 out of 15 teachers recognised the statement as true which was the correct response. Three teachers thought the statement was false and were incorrect and so 3 teachers omitted this question in the pre-test. In the post-intervention tests, 13 teachers were able to concur with the statement and gave the correct response and only 2 teachers found the statement untrue and no teacher omitted the question. This implies that in the post-intervention tests, the majority of the cohort were able to concur with the scientific facts on the particulate nature of matter that 'all molecules of a given substance are identical.

6.3.2 Evidence of knowledge gain in CK through discussions of Curricular Saliency

Figure 6.8 shows extracts of group activities that enabled the researcher to capture the OFTs' discussions on the knowledge component of curricular saliency during the intervention. While the purpose of the activity was to develop teachers' TSPCK specifically the Big Ideas that make the topic of particulate nature of matter, such discussions also resulted in discussions of correct conceptual understanding. The OFTs were given these activities after robust presentations of what curricular saliency meant. The discussions not only ended with teachers giving Big Ideas on the topic but also with discussions around correct concepts if a particular concept was identified as a misconception in teaching a specific Big Idea.

For example, Group 1 indicated that the possible misconceptions for a Big Idea that 'particles are in constant motion' included; *"they [students] do not see the movement of particles in solids, only in liquids and gases.* In this statement, teachers are showing awareness of the correct understanding about the movement of particles even in matter and material that seem very hard at the macroscopic level. Group 1 activity showed later in the intervention that the OFTs were able to see that in a solid-phase, while it might seem as if particles did not have any movement, they were also in constant motion at the sub-microscopic level and that was the correct information.

Similarly, Group 2 made a list of possible misconceptions such as *"solid particles do not move, particles melt in the case of change of state, particles will only move when heat is applied".* Group statements that *"particles melt in the case of change of state"* misconception led to discussions about the correct scientific information. These statements were used to facilitate the correct conceptual understanding by always asking teachers if a specific concept was a misconception, what the correct concepts were, and then consolidate the sessions with providing accurate conceptions. Figure 6.10 shows group 1 and group 2 activities.

Group 1

Student Misconceptions	
What are the big ideas for the topic?	Particles are in constant motion.
What are the typical student misconceptions on this big idea?	They do not see the movement of particles in solids, only in liquids and gases.
CURRICULAR SALIENCY	
What are the big ideas for the topic?	Particles are in constant motion
What do you intend the learners to know about this big idea?	That even in solids the particles are moving, but in constant motion. This is because they are closely packed together. This arrangement will change when the speed is changing ie when heat is added.
Why is it important for learners to know this big idea?	Then the learners will be able to interprete the causes and relate them on their living
What concepts need to be taught before teaching this big idea?	The learners should know the particle arrangement, size remain, (in all these phases of matter)

Group 2

Student Misconceptions	
What are the big ideas for the topic?	Particles are in constant motion
What are the typical student misconceptions on this big idea?	Solid particles do not move • particles melt in the case of change of state • Particles will only move when heat is applied
CURRICULAR SALIENCY	Movement of particles
What are the big ideas for the topic?	
What do you intend the learners to know about this big idea?	• Learners have to understand: re-arrangement of particles due to temperature increase or decrease. • Particles do not melt only the force holding them together • Particles keep moving even on cold or temperature
Why is it important for learners to know this big idea?	• Particles are the same whether in solid, liquid or gas • Other particles have strong forces holding them together (particles of different substances behave differently)
What concepts need to be taught before teaching this big idea?	• Phases of matter • Concepts like: Melting, evaporation, condensation, sublimation, solidification

Figure 6.10: Development of curricular saliency later during the intervention

Group 1 further indicated that in teaching this Big Idea they would emphasise the fact that *"even in solids, particles are moving………..in constant motion*". The OFTs explained the concept as stated: "*they are closely packed together; this arrangement will change when the speed is changing i.e. when heat is added".* Another important conceptual aspect of this Big Idea which was reflected by Group 2 was the concept of forces holding particles together as stated: *"learners have to understand: re-arrangement of particles due to temperature increase or decrease, particles do not melt only the force holding them together, particles keep moving even in cold temperature".*

In these statements, these groups of teachers reflected correctly and a deeper conceptual understanding of the fact that particles will always be moving and that temperature is a factor that determines or changes the speed of the particles. The OFTs stated: *"particles are the same whether in solid, liquid or gas* however, "*other particles have strong forces holding them together"*.

This statement reflects a deeper understanding of learner misconceptions and the correct conceptual understanding that the teachers need to address. Teachers demonstrated an awareness that it is not particles themselves undergoing these physical changes but their particle arrangement and forces that are holding molecules together.

These were quite significant changes in the OFTs' reasoning about CK later in the intervention. Additionally, the OFTs in group 1 stated: *"Learners should know the particle arrangement",* and added: *"size [particle] remain [the same] in all phases".* In the extracts from group 2 above, it is evident that the OFTs were gaining an understanding of the fact that there was an aspect of forces that were holding particles together and these were strongest in solids than liquids and gases.

Question 4b,4c and 4d of the CKs' test was based on the possible misconceptions in teaching the Big Ideas that were discussed intensively during the intervention. Figure 6.11 is an extract of CK test items that correlated with the discussions conducted during the intervention in curricular saliency.

4. Question 1 to 4: are the following statement true (T) or false (F)?

Circle the correct answer and indicate the degree of confidence i.e. 100% sure, not sure or guessing.

(b) Between molecules of a substance there is "empty space". **T/F**

100% sure	*Sure*	*guess*

(c) A molecule of a substance in the solid phase has larger mass than a molecule of the same substance in the gaseous phase. **T/F**

100% sure	*Sure*	*guess*

(d) The forces of attraction between molecules of naphthalene in the liquid phase are greater than in the solid phase. **T/F**

100% sure	*sure*	*guess*

Figure 6.11: Questions corresponding to concepts used to discuss curricular saliency

Table 6.6 are the CK scores for both pre and post-test in question 4b,4c and 4d, where a teacher was either correct or wrong. A correct response was denoted by a ✓ while an incorrect response was denoted by X. In a case where teachers left the question blank, zero was used to represent no response.

Table 6.5: Overall teacher scores in question 4 b, 4c & 4d of the CK tool

Teacher	Question 4b		Question 4c		Question 4d	
	Pre	Post	Pre	Post	Pre	Post
Amanda	✓	✓	✓	✓	x	x
Merriam	✓	✓	✓	✓	✓	✓
Nicky	✓	✓	x	✓	x	x
Thabo	✓	✓	x	x	✓	✓
Mary	0	✓	✓	x	x	0
Harriet	0	✓	x	✓	✓	✓
Sophie	0	✓	x	x	✓	✓
Antana	x	✓	x	✓	x	x
Nosipho	x	✓	x	x	✓	✓
Fiona	x	✓	x	x	✓	✓
Zukie	✓	✓	x	✓	x	x
Noxy	✓	✓	x	✓	x	x
Noreen	x	✓	x	x	x	x
Litha	✓	✓	x	x	x	✓
Andile	✓	✓	x	✓	x	✓
Total No. of teachers with correct responses	8	15	3	8	6	8

In question 4b, when the OFTs were asked whether it was true or false that: '*between molecules of a substance*, *there is empty space',* 8 out of 15 teachers were able to identify the statement as true while 4 out 15 teachers thought it was false, and 3 out 15 teachers did not answer the question. In the post-intervention tests, all teachers (15 out 15) were aware that indeed there were empty spaces between molecules as the whole cohort stated that this statement was true. This is one of the Big Ideas that were discussed during the intervention and explains their observed improvement.

Question 4c required teachers to state whether the statement: *'a molecule of a substance in the solid phase has larger mass than a molecule of the same substance in the gaseous phase'* was true or false. Scientifically, this statement is not true as it is argued that during the phase change the particle arrangement changes causing a change in the spaces between particles as particles are freer to move in the gaseous phase than solid phase.

In the pre-intervention test, the majority of teachers thought this statement was true; it was only 3 out 15 of teachers were able to see that the statement was not true. On the other hand, 8 out 15 of the OFTs, were able to understand that this statement was incorrect after the intervention and gave the correct response while 7 out of 15 retained their misconceptions regarding this concept. In question 4d the OFTs were asked to state whether it was true or false that: '*the forces of attraction between molecules of naphthalene in the liquid phase are greater than in the solid phase'*.

In the cohort of 15 teachers, 6 out of 15 in the pre-tests gave correct responses. Scientifically speaking, the particles of any substance are more closely packed in the solid phase than in the liquid phase which implies that the forces of attraction, which keep molecules closer to each other, are stronger in solids than in liquids. Therefore, the statement in question 4d is not true. In the post-intervention tests, 8 out of 15 teachers were able to give correct responses while 6 out of 16 teachers retained the incorrect responses even post the intervention while 1 teacher did not answer this question.

Furthermore, the teacher responses reported above were also analysed for confidence levels as depicted in Table 6.6.

Table 6.6: Confidence values for question 4

	Q4(a)		Q4(b)		Q4(c)		Q(4d)	
	Pre	Post	Pre	Pre	Post	Post	Pre	Post
Correct 100% Sure	4	5	2	4	0	3	1	1
Correct Sure	3	4	3	4	0	1	1	1
Guess Right	0	0	0	0	1	1	1	1
Guess Wrong	1	1	0	0	0	0	3	2
Incorrect Sure	2	1	0	0	3	1	0	0
Incorrect 100 % Sure	0	0	2	2	1	0	1	1

As indicated above, teacher responses were categorised into six types of responses namely Correct 100% Sure, Correct Sure, Guess Right, Guess Wrong, Incorrect Sure and Incorrect 100 % Sure. While there was an improvement in the confidence levels of teachers after the intervention especially for question 4a and 4b, the accounts of confidence of for 4c and 4d remained relatively poor before and after the intervention.

In question 4a, 26.6% were 100% sure while 20% were sure of their responses and this increased to 33.3% and 26.6% consecutively after the intervention. In overall, there 46.6% of teachers were sure of their responses prior to the intervention and these confidence values increased to 60% after exposure to the intervention. There were no teachers who guessed correct responses in both pre and post-tests while 6.6% guessed incorrectly in both tests.

In the pre-tests, 13,3% teachers were sure of their incorrect responses and only 6, 67% of these types of responses were evident in the post-tests. Similarly, in Question 4b, 13.3% were 100 % sure and 20 % were sure about their correct responses before the intervention while this slightly increased in the post-intervention tests. The number of 100% sure responses were 26.6% as well as sure correct response was 26.6% in the post-intervention. This meant the level of correctness in the responses increased to 53,3% after exposure to the intervention. There were no responses on the category of both guessed correct and incorrect responses. The number of incorrect sure responses were 0% in both pre and post-intervention tests. The number of 100 % sure responses for both pre and post-tests was 13.3%. There was an overall increase in the confidence values of teacher responses post the intervention compared to their pre-tests that meant their confidence in understanding particles of a substance improved post the intervention.

Majority of teachers left question 4c and 4d without indicating their level of confidence in these two questions. The few responses analysed for confidence levels for question 4c indicated that there were no responses categorised as 100% correct in the pre-tests but this number increased to 20% post the intervention. Similarly, there were no teacher responses on the category of correct sure in the pre-tests but this slightly changed to 6.6% post the intervention. The number of guessed correct responses remained 6.6% pre and post the intervention while there were no guessed incorrect responses in both tests before and after the intervention. The number of incorrect 100% sure responses decreased from 20% to 6.6% in the post-intervention while the number of incorrect sure decreased from 6.6% to 0%.

Lastly, in question 4d, teacher responses remained 6.6% across the response categories of Correct 100% Sure, Correct Sure, Guess Right, and Incorrect 100 % Sure for both pre and post-tests, with no responses for the category on incorrect 100% sure in both sets of the test. Lastly, the number of incorrect 100% sure responses decreased from 20% to 13.3% after the intervention.

The confidence values of the teacher responses were evidence that the understanding of particle sizes and forces of attraction between molecules remained a challenge to the OFTs before and after the intervention with the majority of teachers not indicating their level of confidence across all categories.

6.3.3 *Evidence of knowledge gain in CK through discussions of Representations*

The particulate nature of matter is best explained through models that make use of representations. During the intervention, in facilitating the development and understanding of interpreting the particulate nature of matter through sub-microscopic representations, there were two Big Ideas from which examples and activities were built around. These Big Ideas included: "*there are different types of small bits of a substance with different arrangements*" and *"particles are constant motion".* For example, one of the activities, that the OFTs did later in the intervention required them to reason the Big Ideas mentioned in this section through the knowledge component of representations. In the intervention, different questions were used as workshop activities that would facilitate the development of the understanding of the use of representations to form richer explanations in their teaching.

This gain in knowledge was observed in the manner the OFTs reasoned concepts through representations. For example, in a CoRe that was used as an activity during the intervention, the OFTs were still facing challenges concerning how they reasoned concepts through representations. The OFTs were asked during the intervention to state representations which they would use in their teaching strategies. In the extract in Table 6.7 are responses for group 2 and group 3.

Table 6.7: Extracts of responses for groups 2 and 3 in a workshop activity on representations

Group 2	Group 3

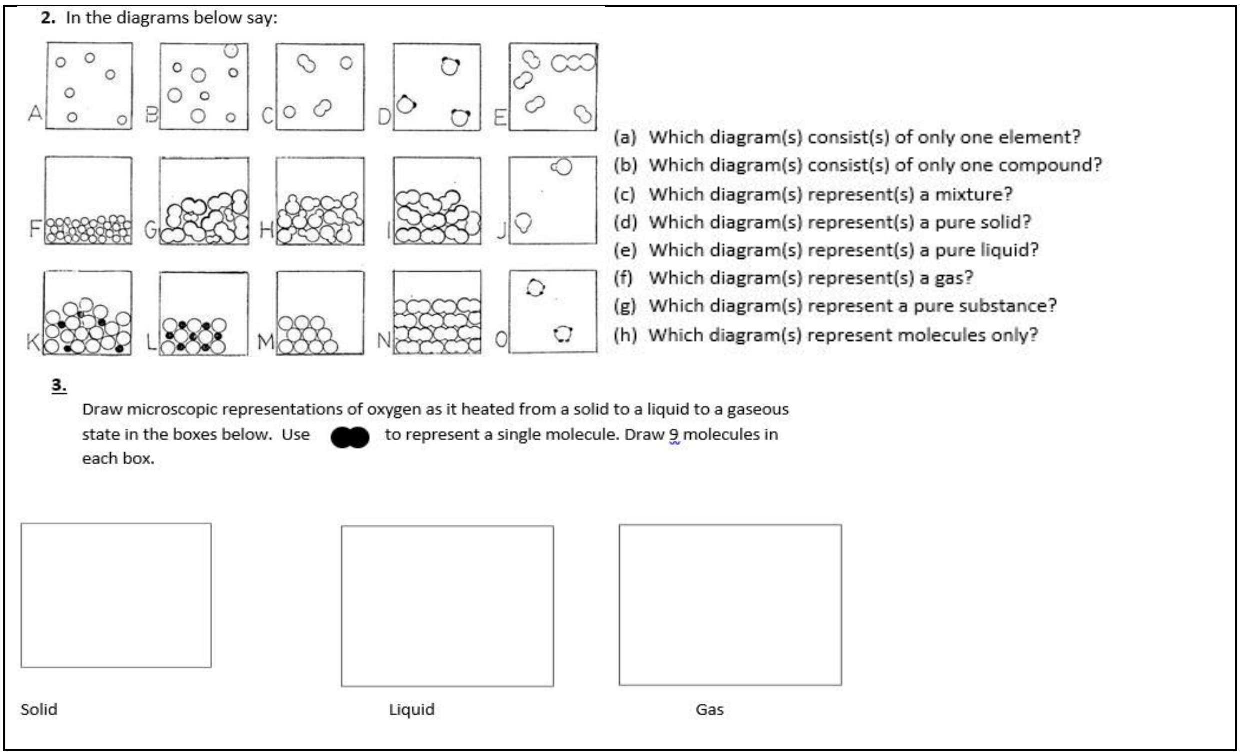
Representations	
What representations would you use in teaching strategy?	Start with macroscopic then follow

Reflections	
What aspects of planning and teaching this idea would you like to reflect on?	Some representations will need more explanation or practical demonstration or video to give clarity as some can easily distort

Representations	
What representations would you use in teaching strategy?	- Posters - Teaching aids, drawings

Group 2 stated that they would “start with macroscopic then follow”. This response is generic and does not specify any concepts of the Big Ideas that they have chosen. While group 3 stated that: “posters, teaching aids, drawn[drawing] were representations which they would use. Group 2 further stated in their reflections “*some representations will need more explanation or practical demonstration or video to give clarity as can easily distract [group 2 meant to say distort]”* This statement was evidence that the OFTs’ use of representations during the intervention was improving as they were able to articulate on concepts that should accompany the use of representations.

Question 2 and question 3 of the CK test correlated with these two main concepts that were discussed in relation to representations as given in Figure 6.12.



2. In the diagrams below say:

(a) Which diagram(s) consist(s) of only one element?
(b) Which diagram(s) consist(s) of only one compound?
(c) Which diagram(s) represent(s) a mixture?
(d) Which diagram(s) represent(s) a pure solid?
(e) Which diagram(s) represent(s) a pure liquid?
(f) Which diagram(s) represent(s) a gas?
(g) Which diagram(s) represent a pure substance?
(h) Which diagram(s) represent molecules only?

3.

Draw microscopic representations of oxygen as it heated from a solid to a liquid to a gaseous state in the boxes below. Use [symbol] to represent a single molecule. Draw 9 molecules in each box.

Solid Liquid Gas

Figure 6.12: Questions corresponding to concepts used to discuss representations

In analysing Question 2, given the fact that there were at least 3 or more responses applicable for each sub-question the teacher responses were categorized into three as indicated in Table 6.9. For example, there were five representations in question 2a which were representations of only one element and these were A, F, I, M and N. This implies that for a teacher to be correct in this question they had to choose at least three diagrams.

Table 6.7: Categorization of teacher responses for question 2

Sub-question	Total no. of correct responses	Correct	**Partial Correct**	**Incorrect**
2a	5	At least 3 correct	1 or 2 correct	No correct answer
2b	5	At least 3 correct	1 or 2 correct	No correct answer
2c	5	At least 3 correct	1 or 2 correct	No correct answer
2d	3	At least 2 correct	Only 1 correct	No correct answer
2e	5	At least 3 correct	1 or 2 correct	No correct answer
2f	7	At least 4 correct	1, 2 or 3 correct	No correct answer
2g	10	At least 5 correct	1 ,2, 3 or 4 correct	No correct answer
2h	8	At least 4 correct	1, 2 or 3 correct	No correct answer

To generate a table of analysis that reflects the teachers' understanding of this item, a correct response was represented by C to match the category of 'correct' according to the Table 6.8, while P was used to represent a partially correct response and X denoted an incorrect response. The results of this analysis are given in Table 6.8.

Table 6.8: OFT's responses in question 2

Teachers	Question 2a		Question 2b		Question 2c		Question 2d		Question 2e		Question 2f		Question 2g		Question 2h	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
1.Mary	C	C	C	C	C	C	C	C	X	P	P	C	C	C	C	X
2. Sophie	P	C	P	C	P	C	P	C	X	P	P	P	P	C	X	C
3. Antana	P	C	C	P	C	P	P	P	X	C	P	C	P	P	C	C
4. Harriet	C	C	X	C	C	C	P	C	P	P	P	C	C	C	P	P
5. Amanda	P	C	P	C	P	C	P	P	X	P	P	P	P	C	P	C
6. Merriam	C	C	C	C	C	C	P	C	X	P	C	C	C	C	C	C
7. Nicky	C	C	P	C	P	C	C	P	X	P	P	C	P	C	C	C
8. Nosipho	P	C	P	C	C	C	C	P	P	C	P	C	P	C	P	C
9. Fiona	C	C	P	C	P	C	P	C	X	C	P	C	P	P	C	P
10. Zukie	P	C	P	P	P	P	P	P	P	C	P	C	P	P	P	P
11. Thabo	X	P	X	C	P	C	P	C	X	C	P	P	P	C	P	P
12. Noxy	P	P	P	C	P	C	P	P	P	C	P	P	P	P	P	P
13.Noreen	P	C	P	C	P	C	X	C	X	C	P	C	P	C	P	P
14. Andile	C	C	C	C	C	C	P	P	C	C	C	C	P	C	C	C
15. Thabo	C	C	C	C	P	C	C	C	C	C	C	C	P	C	X	C
No. of correct responses	**7**	**13**	**5**	**13**	**6**	**13**	**4**	**8**	**2**	**9**	**3**	**11**	**3**	**11**	**6**	**8**
No. of partially correct responses	**7**	**2**	**8**	**2**	**9**	**2**	**10**	**7**	**4**	**6**	**12**	**4**	**12**	**4**	**7**	**6**
No. of incorrect responses	**1**	**0**	**2**	**0**	**0**	**0**	**1**	**0**	**8**	**0**	**0**	**0**	**0**	**0**	**2**	**1**

There is an overall shift observed in the number of correct responses between pre and post responses across sub-questions of question 2.

In the post-intervention tests, the number of correct responses increased compared to pre-intervention tests. For example, in question 2a, it was 7 out of 15 teachers who had correct responses in the pre-tests while 7 were partially correct and 1 teacher was completely incorrect. In the post-intervention tests, there was a shift in the score of correct responses increasing to 13 out of 15. Similarly, in question 2b, 5 out of 15 of the OFTs were able to give correct responses in the pre-tests. This number increased during the post-intervention tests where 13 out 15 of the OFTs were able to give correct responses when asked to identify diagrams that were representing compounds.

This was the trend with question 2c where only 6 out of 15 the OFTs were able to give correct responses when asked to identify diagrams of a mixture while this number increased to 13 in the post-intervention tests. The most challenging task for question 2 was the identification of diagrams that represented pure liquids in sub-question 2d, followed by 2e and 2f where teachers were expected to identify representations of a gas and pure substance consecutively.

In question 2d only 4 out 15 teachers were able to identify at least 2 diagrams which represented pure solids which means only 4 teachers were categorized as correct in this item. Similarly, in question 2e, only 2 teachers who were able to identify at least 3 correct representations of pure liquids and in question 2f, 3 out of 15 teachers were able to give correct responses. The conceptual understanding of OFTs in 2d, 2e and 2f improved post the intervention even though there was still quite a significant number of partially correct responses. In question 2d there were 8 out of 15 teachers who were able to give correct responses after the intervention while there were 9 teachers in question 2e and 11 in question 2f who gave correct responses after the intervention. It is evident from Table 6.10 that teachers' conceptual understanding improved after the intervention.

In question 2g, when the OFTs were asked to give representations of a pure substance, this item was difficult for the majority of the OFTs as it was only 3 out of 15 teachers who were able to give correct responses on this item in the pre-tests. However, in the post-intervention tests, the conceptual understanding of OFTs in pure substances improved after the intervention as 11 out of 15 teachers gave correct responses.

This was the case with question 2h as there were 6 out of 15 teachers who were able to give correct responses in the pre-tests while this number increased to 8 out of 15 teachers in the post-tests. In question 3, the OFTs were asked to draw sub-microscopic representations of oxygen gas as the substance goes through three phases of matter as indicated in Figure 6.12 above. In the cohort of 15 OFTs, 6 were able to draw the correct representations for oxygen in the solid, liquid and gaseous phase while it was only 2 out 15 teachers who gave correct representations for the solid and gaseous phase of this substance. The rest of the cohort (6 out of 15) only gave one representation of oxygen molecules in either solid, liquid or gaseous phase and one teacher completely omitted this question.

In Figure 6.13 are extracts from two of the OFTs written responses. It emerged from teacher representations that the majority of teachers had difficulty in drawing particles of oxygen in the liquid phase. Representations provided by the majority of the OFTs ignored the fact that while particles in liquid phase were loosely arranged compared to solids, these particles were still quite close but were able to move a bit faster and slide past each other. The teachers' representations of the liquid phase had no arrangement and were depicted as if they were in a gaseous phase and had no possibility of sliding past each other because they drew them far apart from each other. For example, teacher Harriet and teacher Mary gave the following responses as given in Figure 6.13:

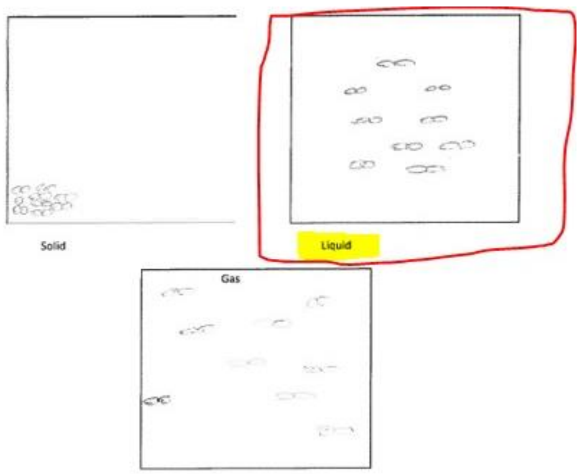
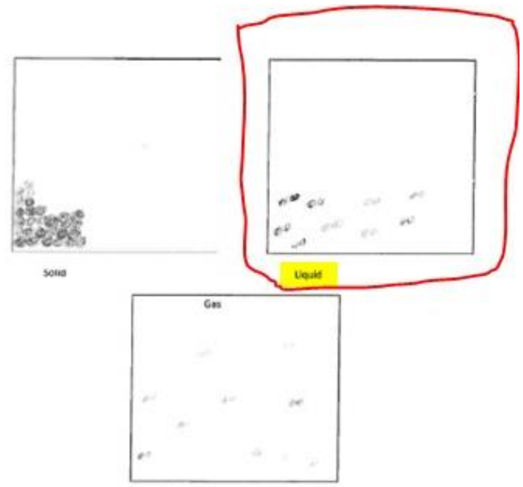
Teacher Harriet	Teacher Mary
	

Figure 6.13: Extracts of pre-test responses for teacher Harriet and Mary in question 3

However, teacher performance in this test item improved in their post-intervention tests. Majority of teachers were able to show the differences in the particle arrangement during the three phases of matter and the applicable spaces in each representation. It was 11 out 15 teachers who were able to make correct responses while 4 teachers still struggled to provide the correct responses for the liquid phase. In the extracts in Figure 6.14 are teacher Mary and teacher Harriet's written responses post the intervention.

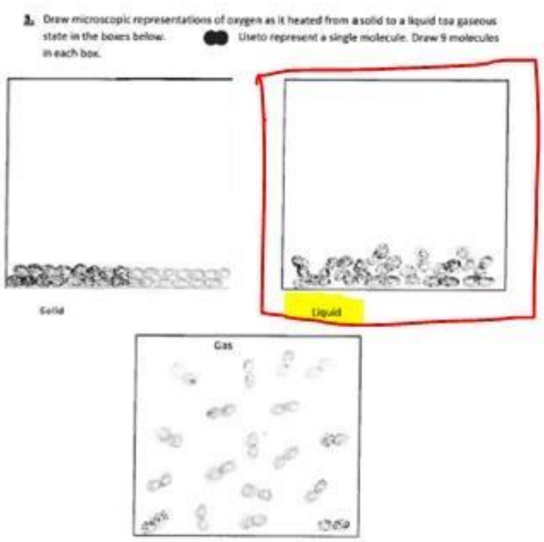
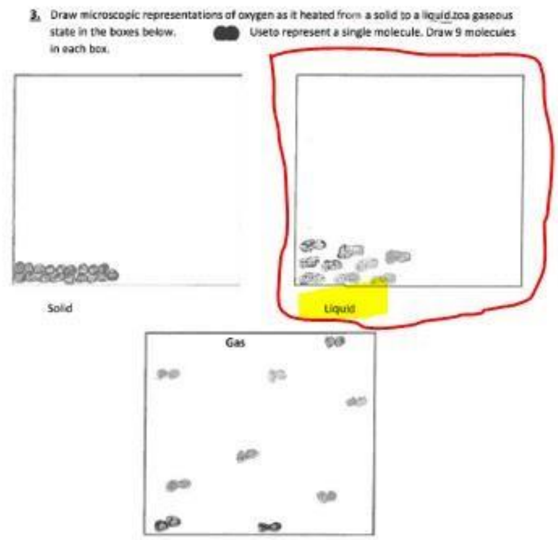
Teacher Harriet	Teacher Mary
	

Figure 6.14: Extracts of pre-test responses for teacher Harriet and Mary in question 3

Emerging from the teacher responses above is evidence that the OFTs were gaining awareness in the importance of paying attention to how they arrange particles during different phases as oppose to their representations prior to the intervention.

6.3.4 Evidence of knowledge gain in CK through discussions of Teaching Strategies

The final component which was put under scrutiny was *Conceptual teaching strategies*. The development of the TSPCK is known as that which is trial and error with a mix of success and failure. In facilitating discussions about Conceptual Teaching Strategies during the intervention, prompting questions extracted from the CoRe were used. The concept of the particulate nature of matter in the gaseous phase was used to facilitate discussions on the knowledge component of teaching strategies. The concepts used in these discussions were sub-concepts around the main concepts that states that '*matter is made up of small bits called particles and particle are in constant motion*.

Table 6.9: Extract from teachers' written core about teaching strategies

Conceptual Teaching Strategies	
What are the big ideas for the topic?	
What effective teaching strategies would you use to teach this idea?	
What questions would you consider important to ask in your teaching strategies	
What ways would you use to assess understanding of learners	
What aspects of planning and teaching would you like to reflect on?	

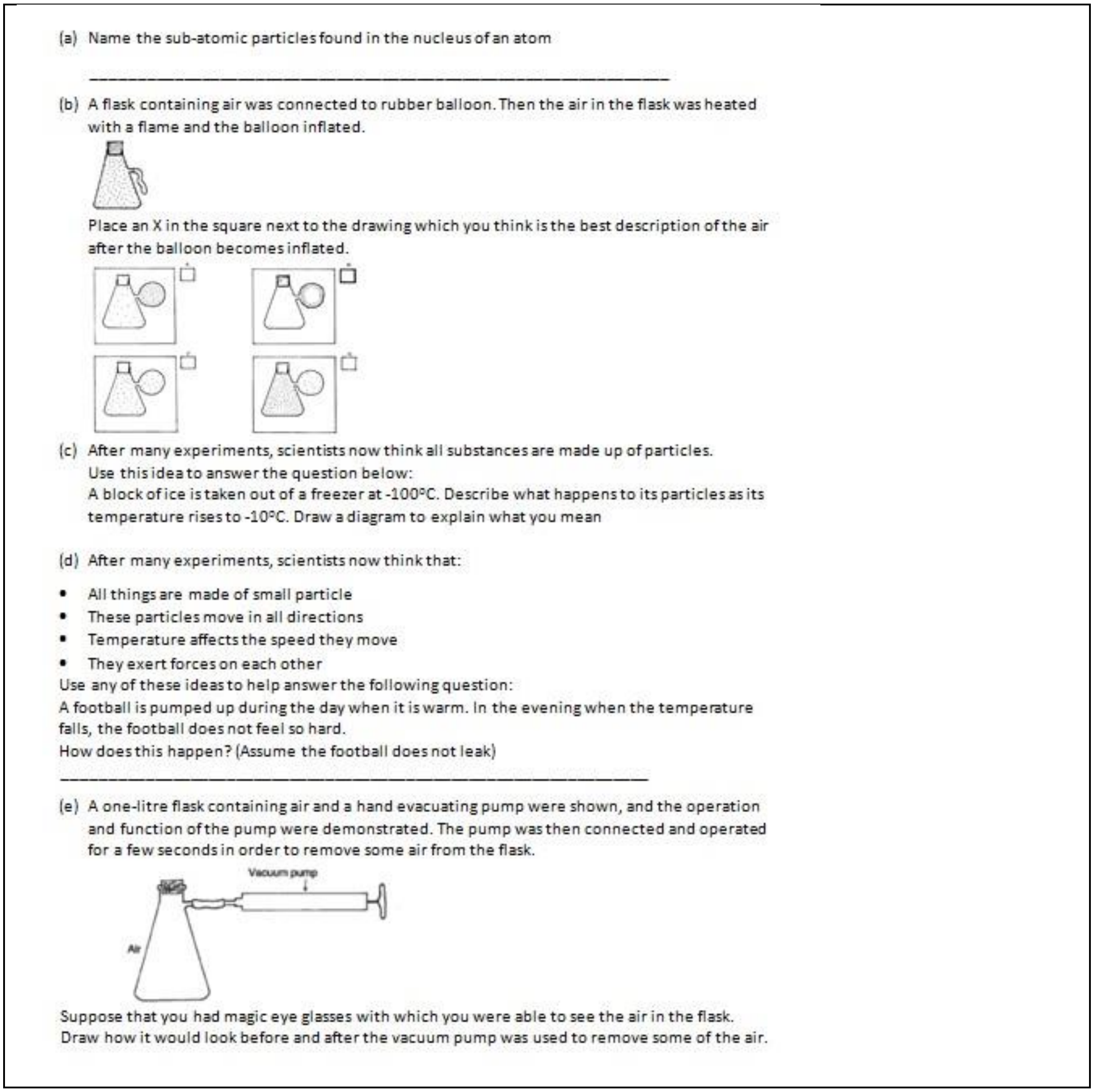
The activity was focused on the fact that conceptual teaching strategies incorporate interactive use of the other four knowledge component discussed in the previous sessions to formulate a conceptual coherent strategy to explain specific concepts in a topic. The OFTs were instructed to consolidate all the activities of previous sessions and devise teaching strategy for a specific big idea. From the response provided by Group 3 in Figure 6.15, it was noted that the OFTs were still struggling with the skill of using other knowledge components to formulate informative teaching strategies.

Teaching Strategies	
What effective teaching strategies would you use to teach this idea?	Practical demonstratio Videos Represetation
What questions would you consider important to ask in your teaching strategies?	Prior knowledge Interest arousing questions Reasoning challenging question knowledge display

Figure 6.15: Extract from teachers' written core about teaching strategies

Similarly, the concept of the particulate nature of matter in the gaseous phase formulated the CK items in question 5. The big ideas that underpinned the both discussions for teaching strategies during PDI and question 5 of the CK test were '*matter is made up of small bits called particles and particle are in constant motion*. The struggle evidenced in OFTs Core entries during the PDI was seen in OFTs'

Question 5a, 5b, 5c, 5d and 5e of the CK tests required teachers to use their knowledge of used to drive discussions on teaching strategies during PDI and as indicated in Figure 6.14. Table 6.10 above is an extract of an activity which OFTs used to reflect their understanding of this concept later in the intervention. Figure 6.15 shows, the last question of the CK tool, Question 5.



(a) Name the sub-atomic particles found in the nucleus of an atom

____

(b) A flask containing air was connected to rubber balloon. Then the air in the flask was heated with a flame and the balloon inflated.

Place an X in the square next to the drawing which you think is the best description of the air after the balloon becomes inflated.

(c) After many experiments, scientists now think all substances are made up of particles.
Use this idea to answer the question below:
A block of ice is taken out of a freezer at -100ºC. Describe what happens to its particles as its temperature rises to -10ºC. Draw a diagram to explain what you mean

(d) After many experiments, scientists now think that:

- All things are made of small particle
- These particles move in all directions
- Temperature affects the speed they move
- They exert forces on each other

Use any of these ideas to help answer the following question:
A football is pumped up during the day when it is warm. In the evening when the temperature falls, the football does not feel so hard.
How does this happen? (Assume the football does not leak)

____

(e) A one-litre flask containing air and a hand evacuating pump were shown, and the operation and function of the pump were demonstrated. The pump was then connected and operated for a few seconds in order to remove some air from the flask.

Suppose that you had magic eye glasses with which you were able to see the air in the flask.
Draw how it would look before and after the vacuum pump was used to remove some of the air.

Figure 6.16: Extract of question 5 of the CK tool

In question 5a, 6 teachers out of 15 were able to recognise the sub-particles under questioning as protons and neutrons, while 4 teachers wrote *'electrons'* and 1 teacher recognised protons as sub-particles of the nucleus. Another teacher gave the charge of nucleus instead of sub-atomic particles and 3 teachers did not answer this question. However, at the end of the intervention, the post-tests revealed that the number of teachers who were able to recognise the sub-atomic particles of nucleus increased from 7 to 13, with only 1 teacher who omitted the question and 1 teacher who only recognised

1 sub-atomic particle. In question 5b, four representations were given and teachers were expected to make a tick or cross next to the diagram to show that they recognised the most appropriate representation of the air inside the balloon after the balloon was inflated. The correct answer was diagram C. In the tests before the intervention only 5 teachers were able to identify box C as the correct response. Another 5 out of 15 teachers identified box A as correct diagram while 2 teachers thought B was best representing the air after the balloon was inflated while 3 teachers omitted the question. However, in the post-intervention tests, 10 teachers of the cohort were able to identify the correct diagram, even though 3 teachers still thought diagram A was the correct one and 2 teachers omitted this question altogether.

In question 5c, the purpose was to probe the teachers' understanding of the particulate nature of matter in terms of expansion. In the analysis, there were no single teachers (0 out of 15) who could respond to this question as they confused the concept of expansion with melting. Teachers interpreted the temperature increase from -100ºC to -10ºC. In Figure 6.17 are teacher Antana and Harriet responses for question 5c, where both responses reflect inability to explain the concept of expansion using the model of the particulate nature of matter. These were the kind of responses that the majority of the OFTs gave.

For example, teacher Antana drew a diagram which indicated that she thought as temperatures were rising, the ice was freezing even more. Another case was teacher Harriet who gave a diagram that indicated that there was going to be no change meaning that ice was going to remain which not fully true. The teacher further stated *"there will be no change in the particles because at minus 10^{0}C ice does not melt".* Teacher Harriet is showing another form of confusion, as she is aware that at both these temperatures water will remain at solid phase, however, it was difficult for teacher Harriet to explain the concept in terms of expansion.

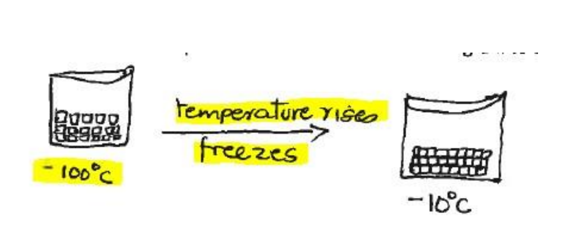
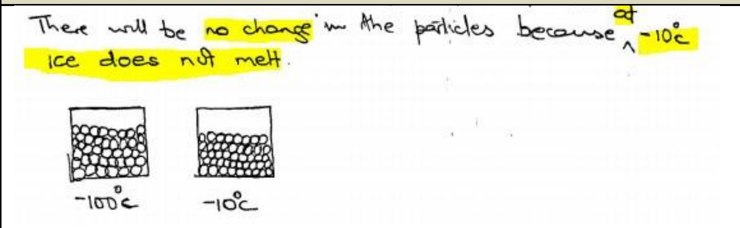
Antana – Pre-test	Pre-test Harriet
	

Figure 6.17: Extracts of teacher Antana and Harriet's pre-test responses in question 5c

In the post-intervention tests, while the OFTs were showing shifts in the manner from which they responded in the same question they still experienced challenges concerning the concept of expansion. It was only teacher Harriet (1 out of 15) who was able to respond close to the concept as indicated in Figure 6.18. However, her response is still not able to explain the fact that as temperatures were increasing to -10^{o}C it meant the volume occupied by a fixed number of molecules will slightly increase the block of ice and ice will expand.

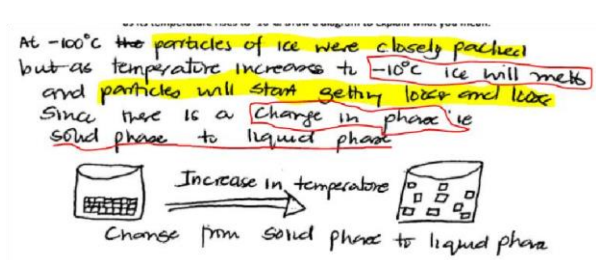
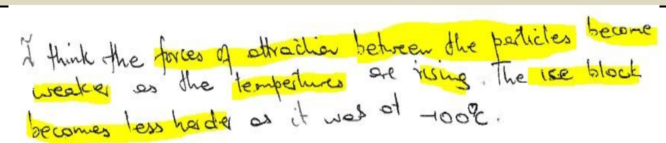
Antana Post test	Harriet Post test
	 I think the forces of attraction between particles become weaker as the temperatures are rising. The ice block becomes less harder as it was at –100 ^{0}C

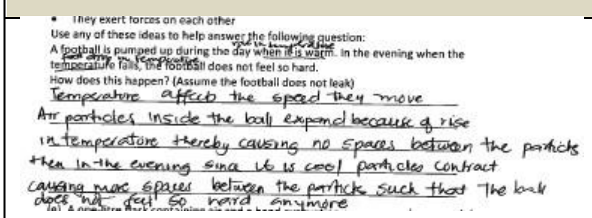
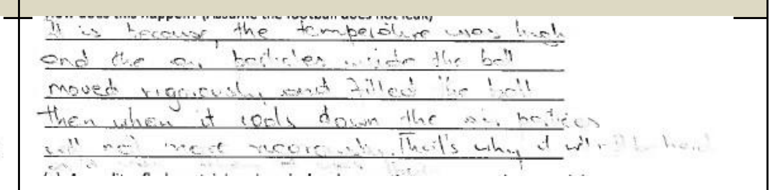
Figure 6.18: Extracts of teacher Antana and Harriet's post-test responses in question 5c

As indicated the majority of the OFTs were still not able to respond to this question correctly even post the intervention. In the diagram above are teacher extracts showing evidence of retained misconceptions and evidence of little improvement in some cases. For example, teacher Antana stated that *at "-100^{0} C particles of ice were closely packed* *but as temperature increases to -10^{0}C ice will melt"* as it was the case in the pre-tests the OFTs responded to this item as though the phenomenon was ice melting or immediate phase change.

However, there was improvement in teacher Harriet's response as she was able to understand that *"forces of attraction between particles become weaker as temperatures are arising".* This is correct because hydrogen bonds that held water molecules in an ordered fashion were getting looser; however, teacher Harriet was not able to further interpret this phenomenon beyond molecules getting looser.

The majority of teachers were unable to explain what happens to a substance, specifically, within a solid phase as the temperature increases within the same phase (ice) using the model of the particulate nature of matter.

In question 5 d, the concept that was questioned dealt with explaining pressure that gases exert due to collisions with each other and against the sides of the container, specifically due to heating using the model of the particulate nature of matter. The majority of the OFTs rather explained this concept through the concept of contraction and expansion, for example in Figure 6.19 are examples from the OFTs written responses.

Antana – pre	Harriet - pre
 • They exert forces on each other Use any of these ideas to help answer the following question: A football is pumped up during the day when it is warm. In the evening when the temperature falls, the football does not feel so hard. How does this happen? (Assume the football does not leak) Temperature affects the speed they move Air particles inside the ball expand because of rise in temperature thereby causing no spaces between the particles then in the evening since it is cool particles contract causing more spaces between the particles such that the ball does not feel so hard anymore	
Temperature affects the speed they [particles] move Air particles inside the ball expand because of rise in temperature thereby causing no spaces between the particles then in the evening since it is cool particles contract causing	It is because, the temperatures was high and the air particles inside the ball moved rigorously and filled the ball then when it cools down the air particles will not move vigorously. That's why it will not be hard as it was when it was hot

more spaces between the particle such that the ball does not feel so hard anymore	

Figure 6.19: Extracts of teacher Antana and Harriet pre-test responses in question 5d

Teacher Antana stated that: *"temperature affects the speed they [particles] move air particles inside the ball expand because of rise in temperature…………in the evening since it is cool particles contract".*

Firstly, the teacher response contains major misconceptions as teacher Antana thinks particles expand due to temperature rise and that particles contact when it is cooler. The effect of temperate in particles does not change or increase or decrease the size of particles but only affects the kinetic energy of the particles. Also, teacher Antana thought the ball was no longer hard enough in the evening because there were more spaces between particles when the temperature drops. In this statement teacher, Antana is explaining the effect of temperature on gas particles but does not mention the fact that these particles are trapped inside the ball and so the effect of pressure against the ball caused by collisions had to be considered. Instead, teacher Antana rather misinterpreted these concerning contraction and expansion. Similarly, teacher Harriet was able to explain that: *"the temperatures was high and the air particles inside the ball moved rigorously……. then when it cools down the air particles will not move vigorously. That's why it will not be hard as it was when it was hot."*

Teacher Harriet is also aware that the temperature increase affects the speed of particles inside the ball. However, in both the responses above, the teachers were not able to explain the effect of this temperature on the speed of the molecules and thus pressure against the ball due to collisions with the walls of the ball. In the post-intervention tests, some of the OFTs retained their misconceptions while some improved. In Figure 6.20 are teacher Antana and Harriet responses after the intervention.

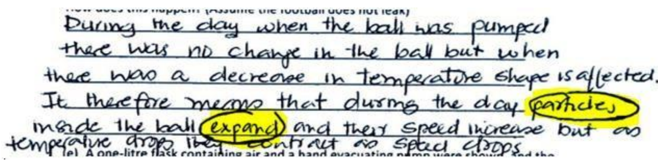
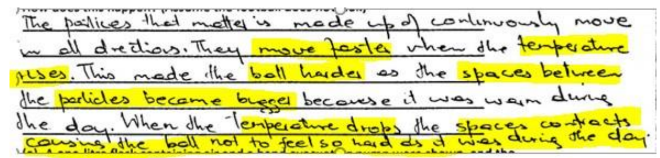
Antana	Harriet
 During the day when the ball was pumped there was no change in the ball but when there was a decrease in temperature shape is affected. It therefore means that during the day particles inside the ball expand and their speed increase but as temperature drops they contract as speed drops	 The particles that matter is made up of continuously move in all directions. They move faster when the temperature rises. This made the ball harder as the spaces between the particles became bigger because it was warm during the day. When the temperature drops the spaces contracts causing the ball not to feel so hard as it was during the day.

Figure 6.20: Extracts of teacher Antana and Harriet’s post-test responses in question 5d

In the extract from teacher Antana above, it is stated that: *“during the day when the ball was pumped there was no change in the ball but when there was a decrease in temperature shape is affected”, it therefore means that during the day particles inside the ball expand and their speed increase but as temperature drops they contract as speed drops”.* In this response teacher Antana still explains the concept of pressure exerted by gases through expansion and contraction without getting into exactly how expansion results in pressure. Teacher Antana also stated that: “*during the day particles inside the ball expand and their speed increase but as temperature drops they contract as speed drops*” In this statement the misconception is that particles expand or contract and several of the OFTs thought like this in both pre and post-tests.

However, there was a slight improvement in the manner in which some of the OFTs understood this concept. For example, teacher Harriet stated, “*the particles that matter is made up of continuously move in all direction. They move faster when the temperatures rise. This made the ball harder as the spaces between the particles became bigger because it was warm during the day. When the temperature drops the spaces contracts causing the ball not feel as hard as it was during the day”.*

This explanation is conceptually correct even though there is no mention of pressure exerted against the walls of the ball. Thus, responses such as this one was accepted. The OFTs improved their knowledge in understanding that the forces of attraction between molecules are always affected by an increase in temperatures.

The final question of the CK test was 5e. It looked into the understanding of the concept of diffusion in the gaseous phase. The question was based on the following: *A one-liter flask containing air and a hand evacuating pump were shown, and the operation and function of the pump were demonstrated. The pump was then connected and operated for a few seconds in order to remove some of the air from the flask*. Teachers were expected to come up with drawings representing the air in the flask before and after some of the air was removed from the flask. The emphasis was on the fact that there will be an equal spreading of air particles throughout the flask and the vacuum pump after the removal of some of the air. In Figure 6.21 are extracts of teacher drawings prior to the intervention.

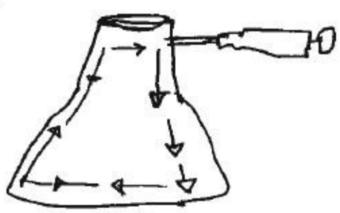
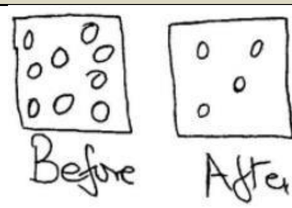
Teacher Antana	Teacher Harriet
	

Figure 6. 21: Extracts of teacher Antana and Harriet pre-test responses in question 5e

This item also proved to be one of the most challenging sub-questions following 5d for the OFTs. In this item, 4 out of the 15 OFTs were able to draw at least acceptable diagrams shown by the diagram given by teacher Antana while teacher Harriet seemed to be able to respond correctly for the flask before some of the air was removed and incorrect diagram for after as indicated above. The rest of the cohort omitted this question (10 out of 15) missing the fact that they were supposed to visualize that they were wearing magic glasses.

Teacher Antana	Teacher Harriet

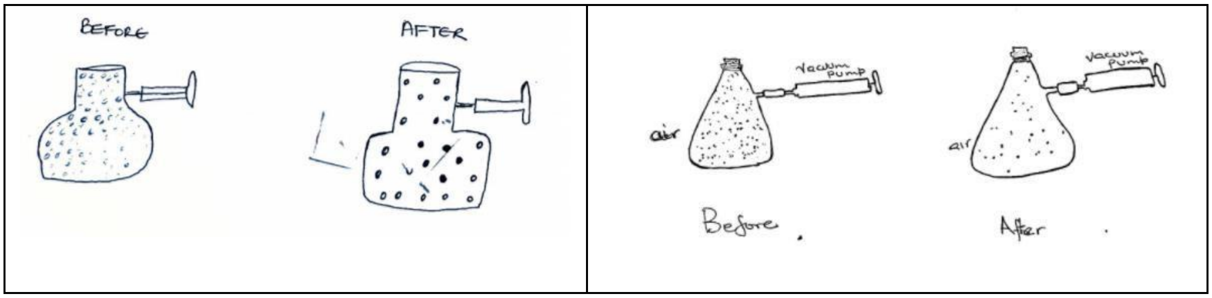


Figure 6.4: Extracts of teacher Antana and Harriet post-test responses in question 5e

There was improvement after the intervention as 8 out of 15 teachers were able to draw correct diagrams reflecting the air in the flask before the air was removed. The diagrams were supposed to reflect that there will be an equal spreading out of air particles throughout the flask and the vacuum pump after the removal of some of the air and that phenomenon is explained as diffusion. It is important to note that the concepts in question 5c and 5d received limited discussions during the intervention due to constraints of time and this can be linked to the OFTs poor performances on these items.

6.4 Conclusion

This chapter investigated the impact of a face-to-face aspect of the intervention on content knowledge in particulate nature of matter. Firstly, the intervention discussed in this chapter had its emphasis on explicitly discussing pedagogical transformation competence for teaching the particulate nature of matter when planning to teach context. Planning to teach CK concepts in the particulate nature of matter were discussed through the five components of TSPCK. While the emphasis of the intervention was on the development of “knowledge to teach science topics”, specifically the particulate nature of matter, the reasoning of this knowledge also exposed teachers’ conceptual understanding of CK.

Secondly, in the analysis, it was revealed that most of the concepts in the particulate nature of matter that were intensively covered through TSPCK component discussions during the intervention, there were visible shifts on the conceptual understanding of OFTs. Concepts such as 5c and 5d that received little coverage during the intervention, OFTs experienced little shift in their conceptual understanding.

In the discussions above, it was noted that development in CK as a result of the TSPCK discussions was not a straight forward process but trial and error and that the constructs under investigation were better captured through the different data source.

CHAPTER 7

IMPACT OF AN EXPLICIT INTERVENTION ON THE QUALITY OF eTSPCK IN PARTICULATE NATURE OF MATTER PRACTICE

In the previous two chapters on analysis the shifts in the quality of the OFTs' CK and TSPCK were carried out in a context of planning to teach the topic of particulate nature of matter. In this chapter, an analysis for the shifts in the quality of the OFTs' enacted PCK at Topic-Specific level are presented. The two previous analysis chapters together with this chapter collectively show the impact of the TSPCK based intervention on the quality of the OFTs' CK and TSPCK. This chapter begins with a short description of the biography of OFTs. Next, a detailed description of the in-depth analysis and method used to analyze and interpret data. Finally, emerging patterns are presented. The chapter ends with a summary of the findings emerging from the analysis of the data presented and consolidated to provide a complete description of the impact of the intervention on enacted TSPCK.

7. 1 Introduction

One of the affordances that brought about the conceptualization of the RCM is that it provided a projected pathway through which the development of teacher professional knowledge could be explored. The RCM outlines the realms of PCK (e.g. *collective PCK, personal PCK and enacted PCK)*, in which a teacher's PCK could be observed in different contexts. In this chapter, the effort to track the impact of the explicit TSPCK-based intervention on the development of the OFTs' TSPCK across the different realms of PCK is continued. The previous chapter reported on the findings related to the observed shifts in the quality of OFTs' personal PCK in the particulate nature of matter. In this chapter, accordingly, the findings of the OFTs' development in their TSPCK as eTSPCK at Topic-Specific level before and after exposure to the intervention are presented.

7.2 Participants

In the previous two chapters, the participants consisted of a group of fifteen teachers who were teaching Natural Sciences as a school subject out of their field of expertise in Province of Eastern Cape. They were referred to as OFTs. In this chapter, the participants were a subset of three teachers drawn from the same group of the OFTs. The three (3) OFTs together with the rest of the group were exposed to an explicit intervention on TSPCK in the topic of particulate nature of matter as described in Chapter 4. The rationale for selecting the three OFTs in the subset was based on the geographical proximity of the schools in which they teach as well as physical accessibility to the schools in terms of road infrastructure and ease of ground terrain. As alluded to in the introduction, in Chapter 1, the Eastern Cape Province is a largely rural-based Province with a sparse population. Secondary Schools are dispersed, some over 100 km from each other. Cohen, Manion, and Morrison (2011) argue that under such circumstances it might be impractical to select such participants randomly and spend an inordinate time travelling before testing the sample. Cluster sampling, as explained in the methodology chapter was used as a sampling method to collect data. For purposes of situating the three OFTs in context to the analysis provided in this chapter, their biography is briefly presented in Table 7.1 for ease of reference. Pseudonyms were used to protect the identity of teachers as well as the identity of their respective schools.

Table 7. 1: Biography of three sub-set of OFTs followed to class

OFT	**Qualification**	**Name of School**	**Proximity**	**Grade**	**No. of years teaching Natural Sciences at the time of Intervention**	**Total No. of teaching experience**	**Particle Nature of Matter concepts taught**	
							Pre- Intervention concepts taught by the teacher	**Post-intervention concepts taught by the teacher**
1. Amanda	Junior Primary Teachers' Diploma (JTPD) (General Sciences)	London Junior Secondary School	**60,1 Km**	8	2	24	Particle Model of matter - The concept of particle model of matter (the three states of matter) - Change of State	Particle Model of Matter - The concept of particle model of matter (the three states of matter) - Change of State - Density of different materials
2. Noreen	Senior Primary Teachers' Diploma (SPTD) (General Sciences	Eastern Secondary School		8	2	24	Particle Model of matter - The concept of particle model of matter (the three states of matter) - Change of State	Particle Model of matter - The concept of particle model of matter (the three states of matter) - Change of State
3. Sophie	Senior Primary Teachers' Diploma (SPTD) (Biology)	North Junior Secondary School	**39, 3 Km**	8	2	16	Particle Model of matter - Atoms-building blocks of matter (Elements, Compounds) - Particle Model of Matter - Change of State	Particle Model of matter - The concept of particle model of matter (the three states of matter) - Change of State

Note : Junior Secondary School – A school that usually includes Grade 7 to 9
: Secondary School -A school for pupils between 11 or 12 and 17 or 18 and includes Grade 8 to 12.

*Pseudonyms have been used in the table above to protect true characters of the participants in the particle nature of matter of the OFTs as a result of the TSPCK based intervention.

*Pseudonyms have been used in the table above to protect true characters of the schools of the participants

The data presented in Table 7.1 indicate that the three (3) OFTs in the subset sample were trained as primary school teachers. In South Africa, Primary School qualifications enable the teacher to teach from Grade 1-7. These school grades are located in what is referred to as the Foundation Phase of the South African Basic Education system. The Foundation Phase is followed by a phase called Intermediate Phase (Grades 4-6), then Senior Phase (Grades 7-9) and lastly the Further Education Phase (Grades 10-12). Table 7.1, shows that the teachers were teaching Grade 8, a grade allocated two (2) school phases up from the Foundation phase.

Two of the OFTs, teacher Amanda and Noreen each had 24 years teaching experience and one OFT, teacher Sophie had experience of 16 years, with only 2 years of these in teaching Natural Sciences. At the beginning of this study, it was indicated that one of the key issues leading to Out-of-field teaching is a high teacher attrition rate for science teachers in rural areas (Hobbs, 2011).

Table 7.1 provides the specific concepts from the broader topic of particulate nature of matter which OFTs chose to teach before and after the intervention. They each taught the same concepts to different classes of Grade 8 before and after the intervention. No class was taught the same concepts twice. The lessons were video-recorded. Teacher Amanda taught the three states of matter and change of state in her pre- and post-intervention video-recorded lessons (with different classes of Grade 8). Additionally, teacher Amanda also added the concept of density in her teaching after the intervention. Teacher Noreen taught the three states of matter and change of state in her pre- and post-intervention video-recorded lessons.

Teacher Sophie taught the concept of Atom as building blocks of matter and covered the topic on Elements and Compounds. The teacher also taught the particulate nature of matter, touching on the change of state in both her pre and post-intervention lessons.

The three subsets of the OFTs were taught during their normal school days and they used their NS periods to teach. Each teacher had two lessons before and after the intervention. In the pre-intervention lessons, each lesson was 30-35 minutes long. The post-intervention lessons were more focused and as a result each of the two lessons per teacher took 20-25 minutes.

Section 7.3 analyses the video-recorded lessons that were collected. These videos of the OFTs' TSPCK in the particulate nature of matter in classroom practice that were transcribed verbatim. The texts were then analysed and coded for evidence of teaching moments showing TSPCK episodes using methods of qualitative in-depth analysis explicit of TSPCK. According to this qualitative in-depth analysis method, the first step includes identification of teaching segments that demonstrates the presence of TSPCK episodes. A TSPCK episode is defined as a moment where there is evidence of the interactive use of two or more TSPCK components. The second step was to identify the types of TSPCK components found in the TSPCK. The second step was to identify the types of TSPCK components found in the TSPCK. In describing the components in a TSPCK episode, the TSPCK components were abbreviated for ease of analysis: Learner Prior Knowledge **(LP)**, Curricular Saliency **(CS),** What is Difficult to teach **(WD),** Representations **(RP)** and Teaching Strategies **(CT).** The third step involved describing the nature of the interaction; for example, whether the components in a TSPCK episode emerged in a linear format or an integrated format. Linear formats are characterized by a linear emergence of the components, one after another. An interwoven interaction reflects TSPCK components emerging intermitted into each other (Mavhunga, 2018). For example, in a case where a linear sequence as depicted in a TSPCK episode with emerging components followed each other a dash (-) was used to represent such a sequence. If the component interactions were interwoven, a forward slash (/) was used to represent that sequence. Therefore, an emerging TSPCK episode of CS/LP-RP as an example, means CS and LP were used in an interwoven manner as represented by a forward slash (/) and linked to RP which was used as a standalone as denoted by (-). In a case where a specific component was implied such a component was underlined in italics, (for example*, LP.* As stated in the previous sections that components of TSPCK were abbreviated for ease of analysis.

The last step involved representing the identified TSPCK interactions in a TSPCK MAP an idea adopted from Park and Suh (2019). The identified TSPCK episodes were then rated with the assistance of two additional raters using a TSPCK rubric designed to categorize TSPCK observed in action (Miheso, 2018). The rubric was used to categorize the extent of the observed component interactions. The two raters were chosen based on their familiarity with TSPCK and experience as science teacher educators. The process of scoring the identified episodes required scoring the identified TSPCK episodes individually and thereafter sharing the scores for agreement. The Cohen-Kappa inter-rater reliability index was used to calculate the reliability indices (McHugh, 2014). An inter-rater reliability agreement of 0.81 was established. In a case where there was disagreement, all the three raters including the researcher discussed the differences until consensus was reached.

The categorized TSPCK episodes were presented in pictorial representations called teaching profiles that reflected the different TSPCK episodes captured in a lesson. A TSPCK teaching profile represents a timeline versus type of TSPCK episodes in a lesson. The advantage is that it shows the number of different types of TSPCK episodes as depicted in the categories of the TSPCK rubric for the classroom and the time when that episode emerged in a lesson. Subsequently, these analytical tools allow comparison of participants in the pre- and post-intervention classroom observations.

7.3 Data processing

In response to the dynamic nature of PCK and the difficulty of capturing action, different data sources were used to respond to the research question in this chapter. The research question that this chapter answered was ‘What impact does the intervention have on the quality of OFTs’ eTSPCK in the particulate nature of matter’. The primary data sources that provided insights about shifts in the quality of the OFTs' enacted TSPCK were video-recorded lessons in the particulate nature of matter collected pre- and post- the intervention.

Table 7. 2: The overall data collected to capture enacted TSPCK in particle nature of matter

OFTs	CK tools in the particulate nature of matter		TSPCK tools in the particulate nature of matter		PRE-INTERVENTION DATA	POST-INTERVENTION DATA
	Pre-Tests	Post-Tests	Pre-Tests	Post-Tests	Videos	Videos
1. Amanda	29.1 %	50.6 %	1 (Limited TSPCK)	2 (Basic TSPCK)	Particle Model of matter - The concept of particle model of matter (the three states of matter) Change of State	Particle Model of Matter - The concept of particle model of matter (the three states of matter) - Change of State - Density of different materials
					2 lessons: 2 x 35 min	2 lessons: 2 x 22 min
2. Sophie	31.6%	58.3%	2 (Basic TSPCK)	3 (Developing TSPCK)	Atom - Atoms-building blocks of matter - Elements - Compounds Particle Model of Matter Change of State	Particle Model of matter - The concept of particle model of matter (the three states of matter) - Change of State
					2 lessons: 2 x 30 min	2 lessons: 2 x 20 minutes
3. Noreen	25.3%	73.4%	2 (Basic TSPCK)	3 (Developing TSPCK)	Particle Model of matter - The concept of particle model of matter (the three states of matter) - Change of State	Particle Model of matter - The concept of particle model of matter (the three states of matter) - Change of State
					2 lessons: 2 x 30 min	2 lessons: 2 x 20 min

In section 7.4, the emerging patterns from the data analysis are discussed in detail.

7.4 Emerging patterns from detailed data analysis

As explained in Chapter 3, given the complex process of capturing and analysing for the enacted PCK, the findings from the analysis of the lessons delivered by the three OFTs were best presented as individual mini-cases within the case study. One of the key findings across the teachers was the poor quality of teaching in the pre-intervention lessons. Teachers used common knowledge about boiling water and ice water as concepts that made up the topic of the particulate nature of matter, there were, however, observable shifts in how teachers taught the particulate nature of matter topic after the intervention. Increased number of proficient TSPCK episodes after the intervention showed the shifts in the quality of TSPCK post the intervention. There were significant shifts in the focus of the lessons after the intervention where teachers moved away from long winded questions that were reflecting language difficulties from both teachers and students to focusing on the explanations of the particulate nature of matter.

TSPCK episodes are instances of explicit PCK identified from transcripts of lesson observations which could also be teachers' spoken accounts of their teaching or written (Park & Oliver 2008). In this study, TSPCK episodes observed across the two lessons of each of the OFT were identified through transcribed video recordings of teachers teaching the particulate nature of matter. During classroom observations, there were instances of code switching between English and Xhosa during teaching. Such instances were translated by researcher. In order to ensure that the meaning stayed the same after translation, a square bracket with English translation was inserted after each Xhosa word with the phrase "a Xhosa word meaning …….". TSPCK episodes were then presented in the sequence in which they occurred in the lesson as 'teaching TSPCK profiles. Table 7.1 presented constructed 'teaching TSPCK profiles' for each OFT, placing pre- and post-intervention against each other to display shifts.

Due to the intricacy and the arduous nature of analyzing data for eTSPCK, in the section below, teacher Amanda is used as an example of the process of in-depth analysis that was followed to arrive in the findings summarized above. The presentation of teacher Amanda begins by giving an overview description of the lesson taught as drawn from the recorded video lessons, listing identified TSPCK episodes in the sequence of their occurrence in the lesson, scoring of the observed TSPCK episodes and reflecting the findings in a pictorial representation called teacher profile.

CASE 1: TEACHER AMANDA

Given below is the overview description of Amanda's pre-intervention lessons based on the concepts of phases of Matter and Change of State.

(i) Overview description of the pre-intervention lessons

In teaching the concept of the phases of matter, teacher Amanda spent most of the lesson questioning students about concepts that were more scientific language related than those of the topic at hand with few snippets of the particulate nature of matter. For the analysis in this chapter, only one lesson from teacher Amanda is discussed due to the difficulty of the teacher to focus the lesson into particulate nature of matter beyond language prompting questions. The detailed analysis for the second lesson is given in the list of Appendices as Appendix 14

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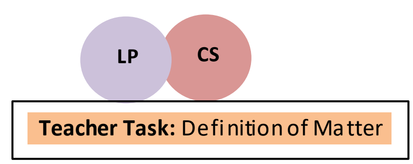
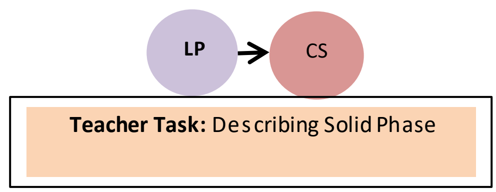
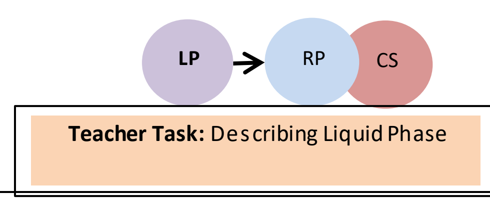
Table 7. 3: In-depth analysis for teacher Amanda's pre-intervention lesson 1

Lesson 1	
Extracts of Amanda's teaching in sequence	Comments/Qualitative in-depth analysis
0-2:27 min: Definition of Matter **Teacher Amanda**: [writing on the *black board, 'THE PHASES OF MATTER'] The phases of Matter, if you talk about phases you also talk about the states. The states of matter. Before we go to that lesson, can one of you tell me what is a matter? Before we go to phases of matter what is a matter? What is a Matter? What is a matter class, please let us participate try to say something, you know, you are doing Grade 8, obviously once you are in Grade 8 you know these things? Yes, Learner X* ***Learner X****: Matter is everything around us* *Teacher Amanda: Very good matter is everything around us [writing on the board] …. Class* *Class [singing]: matter is everything that is around us* ***Teacher Amanda****: So (writing on black board: Matter is everything around us) … that's what she said (writing on black board again) Matter is anything that occupies space and has mass or weight, Class what is matter (pointing at the definition she wrote on the black board)* *Class (singing): Matter is anything that occupies space and has mass or weight* ***Teacher Amanda****: Again* *Class (singing): Matter is anything that occupies space and has mass or weight* ***Teacher Amanda:*** *(pointing at Learner Mirriam's first definition): which is exactly the same as she said "Matter is everything around us"*	**Comment:** The focus of this discussion was on defining Matter that is fundamental in understanding the phases of matter. **In-depth Qualitative Analysis**: **Teacher Amanda's action**: before introducing phases of matter, teacher prompted into learners' thinking about matter and asked what matter is? **Learner's role**: Learner responded and provided a broad generic answer which is less scientific that "*Matter is everything around us"* which made teacher Amanda aware of knowledge that learners had (LP) **Teacher Amanda's action:** teacher first acknowledges the learner response and further expands on the Learner knowledge (LP) at hand with correct scientific standard definition of matter, incorporating concepts such as space, mass and weight into to standard definition of matter (CS) as she said "*Matter is anything that occupies space and has mass or weigh"* and makes learners to repeat this definition which she confirmed in the post-lesson interview as wanting to emphasize the specific features of the expanded definition. In this classroom action, teacher used TSPCK components of LP and CS in an interwoven manner (LP/CS) to teach the concept of matter as guided by learner response. A TSPCK Map for this teacher action is given below: 
2:27-5:02min: Liquid Phase and Solid Phase ***Teacher Amanda:*** *Okay…without wasting time our topic is about the phases of matter (Pointing at this topic from the black board) that means the states of matter…..eeeeh can you tell me what do you see in front of you when you are looking in this table, what do you see, just raise up your hand what do you see in front of you (taking away the stick [this one must not be seen] referring to the stick that was also in the table together with the equipment) what do you see in front of you, Yes Lisa* *Learner Lisa: I see the empty bottles* *Teacher: good, what else do you see? in front of you (pointing at another student) Yes?* *Learner: I see glass* *Teacher: Yes, you see a bottle (showing up the empty glass to the entire class) an empty glass bottle* *What else do you see there are so many things, yes? (pointing at another student)* *Learner: I see the teachers' book*	**Comment:** The focus of this discussion was to learn about liquid and solid phases using water as example **In-depth Qualitative analysis:** **Teacher Amanda's Action:** Teacher Amanda brought water (as example of matter) in liquid phase and in solid phase and asked learners to identify these two phases of matter and thus further building up from definition of matter which learners understood as everything around us (for example water) (CS). This example of water as matter can be seen as a macroscopic representation of the concept at hand, thus teacher Amanda is introducing the topic of "phases of matter" through use of conceptual representation (RP). **Learners' Role:** Learners are openly naming all materials around them including desks, books and glasses, water and ice **Teacher Amanda's role:** As learners respond openly to other less relevant materials, teacher Amanda acknowledges these as examples of matter but only write on

Teacher: Okay…the teachers' book, okay (pointing at another student) *Learner: I see water* *Teacher: Okay, (repeating what the student said) the water in the bottle, very good (the teacher quickly* ***points*** *at the ice in the tubs and realizes that student cannot see as all these are in her station table so learners can only see tubs of margarine but not what is inside), okay you cannot see what is inside these containers is it? But if I can ask each group to have a look (while distributing the ice to each group) tell me what do you see before you tell me what it, just touch it then tell me what is it, no don't tell lie, tell me exactly what is it, you tell me, touch it then you'll tell me what is it (responding to the whispers of one of the groups) what do you see* *Teacher: Yes, I think everybody has seen it, what is it? In the containers, you raise up your hand, yes Pretty what have you seen? (pointing at a student)* *Learner Pretty: I see an ice* *Teacher: very good, class what have you seen from the containers* *Class (singing): I have seen the ice* *Teacher: (writing on the blackboard: Ice), then picked up a bottle filled with water, from this bottle what do you see?* *Class: I see water* *Teacher: (writing on Blackboard) water*	the blackboard those relevant to the topic at hand thus adding value to learner knowledge by directing emphasis only to water in liquid and solid phase as she puts water (water bottle) and ice. Teacher Amanda is guiding learners to establish the different phases of matter through use of representations. No TSPCK as no response is seen using the TSPCK components in an interactive manner
5:02:8:35 min: Gaseous Phase *Teacher: who can tell me if you can boil this water, what can you see? (repeating the question many times) just tell me, you have been boiling water each and every day at your homes before you make tea,* *Learner: Evaporation* *Teacher: okay good, but tell me what do you see before, that is a process, he is telling me about the process, what do you see when the water boils, when the water boils what do you see, just raise up your hands and try, what do you see, what do you see when the water boils what do you see, nobody has seen water boiling? Is it? You have never seen the water boiling?* *Is it what you are trying to tell me? Grade 8 have you ever seen the water boiling* *Class: Yes* *Teacher: Then when the water is boiling what do you observe what do you see? What do you see, you forgotten? Every day before you make tea for your mother or your grandfather or your grandmother, you see something, what is it? Just try, yes (pointing at student)* *Learner: Bubbles* *Teacher: at least, you see? you call them bubbles okay, what else? What else? Yes (pointing at another student) yes Merriam* *Learner: I can see the warmth that that goes through (loss of the word for lid and used his hand to show this)* *Teacher (helping her and finishing the sentence for her) through the lid of the pot? (Student Merriam repeating after the teacher, through the lid of the pot) What does it look like)* *Merriam: It looks like…* *Teacher: at least she has given us a clue, what does it look like? Something that is coming out from the pot or from the kettle, what is it? How does it look like?* *Learner: Like a smoke*	**Comment:** In this episode teacher Amanda is focusing on gaseous phase **In-depth Qualitative analysis:** **Teacher Amanda's Action:** the teacher introduces learners to gaseous phase of matter by asking learners' observations when one boils water. The teacher uses a scenario that she believes is part of learners' day-to-day lives. In this scenario teacher, Amanda encourages her learners to picture themselves boiling water for their grandparents' cup of morning tea (conceptual progression with real-life example). **Learners XYs' response:** the learner responds in the language that they use at home, as he mentions that when water is boiling smoke comes out and this helps teacher Amanda to build scientific terminology of learners from their day to day language. **Teacher Amanda's action:** teacher Amanda acknowledges and confirms learner response with "very good" as compliment and uses this learner response to take learners into correct scientific language as she writes on the blackboard (water vapor) emphasizing that such smoke is called water vapor. In addition, teacher Amanda consolidates the session by revisiting the two previously

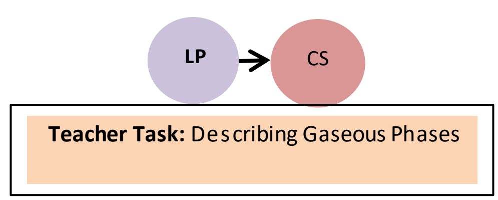
Teacher: very good it looks like a smoke, it looks like a smoke, then we call that (writing on board) water vapor, what do you call that smoke? [pointing at the 'water vapor' she has just written on the blackboard] what do you call that smoke" *Learners: Water vapor* *Teacher: again* *Learners: water vapor* *Teacher: Okay that tells us, matter has got (showing 3 with her fingers) three phases, matter has got how many phases class?*	discussed phases together with gaseous phase scenario with a statement that, the exercise of identifying three examples of phases of water was an indication that matter has three phases using real-life scenarios such as liquid water which was represented by a water bottle, ice water which freezes when put on the refrigerator and water vapor when boiling water. No TSPCK as the teacher is probing and helps learners to understand scientific language.
<u>8:35-14:16min: Describing Solid Phase</u> *Teacher: who can tell me the three phases you have seen, (realizing that they have not seen the water vapor) okay let's take it for granted although you will be going to the kitchen to observe when the water boils, which phase or stage, its either you say phases, states, stage (writing on the black board) those are the synonyms pointing at the black board) at which stage does matter starts from? Who can tell me as you have seen? You have seen you have said (taking ice tub and pointing inside it) what is in here?* *Class: Ice* *Teacher: You have seen what this is. (showing up water bottle)* *Class: Water* *Teacher: Then when the water boils, we see the (pointing at water vapor written on the blackboard) then which stage or which phase do you think the matter starts with, just hands up, tell me, do you get the ice from the river?* *Class: Mumbling* *Teacher: No no no don't don't sing just raise up your hand, do you get the ice from the river?* *Class: No* *Teacher: What do you get from the river, yes Pretty* *Learner: You get water* *Teacher: very good, you get (showing up water in the water bottle) water from the river but because the phases of matter have got stages, the first stage is a solid stage (writing on black board), the first stage is a solid stage and who can tell me, what do I mean when I am saying something is solid, what do I mean when I am saying something is on solid , what is your understanding about solid, if you say something is solid, just tell me your understanding, you can even tell me in Xhosa if you think that's how you understand it, when you saying something is solid, Yes …(not clear) pointing at a student* *Learner: Ice* *Teacher: something which is solid that means its ice (writing on blackboard under solid stage-ice) why do you say ice is an example of the solid stage, why do you think so? Why do you say so, yes Bangani?* *Learner: Because it doesn't have a space* *Teacher: No no no no, you have tried something but you have said the opposite, why do you say a solid stage you have got an example of an ice why? It's because when you talk about something which*	**Comment:** In this episode the teacher is describing the solid phase, focusing on characteristics of solid materials **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** In the teaching segment teacher, Amanda is explaining to learners that matter starts with solid and this explanation is seen in this statement "because *the phases of matter have got stages, the first stage is a solid stage".* The teacher then asked for learners' understanding of solids. **Learner's Role:** the student response is indicative of limited scientific understanding of what is meant by solid stage as the learner only gave an example of solid (LP) **Teacher Amanda's role:** the teacher acknowledges learner response and further adds value to the learner response as she first put it to the class that ice is an example of solid phase and further asks leaners why is ice an example of solid thereby throwing the question back to the class to show learners that while the learner gave ice as his understanding of solid but ice is only an example. **Teacher Amanda' s role:** The teacher builds up from the learner response who gave ice as example and further adds other obvious examples such as glass beaker and chalkboard duster, as objects that are not easy to break and hence regarded as solids (CS). Teacher Amanda further explains using the concept of particle nature to explain the difference between solids and liquids and the orientation of particles of matter during these two states of matter. Teacher

is solid it's something which cannot break easily when you say something is solid, this duster is solid (showing the duster t the class), this glass is solid (showing the 100ml glass beaker) siyevana (siyevana is a Xhosa word which means, do you hear me?) but the paper is not solid it can break easily, you can fold it easily okay then how do you make the water because we said we get the water from the river as a liquid, how do you make ice who can tell me, how do we make ice, how do we make ice, yes Lisa *Learner: You put it in the fridge* *Teacher: Very good, (writing on blackboard) you put it in the refrigerator, then after you have put water in the refrigerator, what will happen? You put water in the refrigerator then what will happen, yes (pointing a student)* *Learner: The water will change from liquid to solid* *Teacher; now can you tell me what is going to happen, that is good, what you have told me is good but if you put water in the refrigerator, the water will do what….and becomes ice? If you okay let's say the type of refrigerator it's a freezer, let's say you have used the freezer then what will happen to the water, at least this is a clue, if you put the water in the freezer what will happen to the water, what will happen to the water, if you put the water in the freezer what will happen in water, yes Mbiza* *Learner: Water will freeze* *Teacher: Very good, then that means the water freezer (WRITING ON BLACK BOARD) THE WATER freezes and becomes ice, the water freezes and becomes ice and once the water freezes and becomes ice it is in the solid stage (pointing on the blackboard). who can tell me why the water freezes when you put the water in the freezer, why? Why? Why? Okay it's because the particles are closely packed, (writing on the bb) it's because the particles are closely packed. Here if you look at this water (demonstrating with the water bottle in her working station) it moves, can you see, it moves that means the particles, there are some small spaces in between but with the ice they cannot move, they cannot move then they freeze then that effect of being closely packed they make them to be in the solid stage*	Amanda starts explaining with macroscopic explanations while relating the concept with learners' day to day life experiences (CS) The teacher further uses the particulate explanations to explain what happens at a microscopic level during solid phase of matter by stating that in solid phase or ice particles are closely packed. The interactive use of LP-CS in describing the solid phase is portraying a simple TSPCK episode and the resulting TSPCK Map is given below 
<u>16:37-21:37min: Describing Liquid Phase</u> *Teacher: Once it's out of the fridge it defreeze (writing defreeze and highlighted it on the black board), once it's out of the refrigerator or out of the freezer it defrozes, it defrozes or it (then this water) it defrozes or else it has …..if we have an ice and its heated let's say when we go to the kitchen we will see this if we are having ice and its heated before we go to the kitchen to heat it because of the room temperature it affected the ice then it does what, I want to hear from you, because of the temperature of the room temperature, what has happened to the water, let's try please, let's Say okay let's say let's have an eeehhhh an idea lets imagine that we are in our homes and we've got a candle and your candle it's in the solid stage is it and put on a light then the candle you'll find that the wax is no more the wax what is happening, in the middle what has happened to that wax* *Learner: Mumbling* *Teacher: come again (trying to attend to the mumbling students with hope of getting answer to the groups of students that are mumbling) …. …., Ngxabe (pointing at student Ngxabe) … what has happened? Okay if you are not thinking about the candles*	**<u>Comment:</u>** In this discussion teacher Amanda is explaining the concept of liquid phase **<u>In-depth Qualitative analysis:</u>** **Teachers Amanda's role:** Teacher Amanda explains further that if for example ice water is taken out of freeze, while continuously emphasizing the effect of heat during this process. The teacher repeatedly asks learners to share their understanding of the process that causes the change of phase from solid to liquid. The teacher uses different examples to subtly guide learners' thinking into the gist of the discussion as she asks learners what happens when you have candle light on and the wax of the candle disappears.

at……… (then Merriam cuts her as she is trying to say something) …. yes Merriam, just try, try *Learner: Mumbling* *Techer; Come again* *Learner: Not clear but saying something* *TEACHER: Yes my question is: once it has changed from the solid stage where it was in solid stage, it was thick, now it's in the liquid stage, what is happening, I want that word, may be ice don't even think about the candle at home here is the ice in front of you, the ice in front of you what has happened, this word starts with M, the word I am looking for it starts with M, that means the ice has……. but the word I am looking for starts with the letter M (Writing M on the blackboard) what has happened, the word I am looking for starts from starts with the letter M, yes XF (pointing at student XF)* *Learner: It's melted* *Teacher: (with a excitement) its melting, it melts very good (writing on blackboard) it melts so here we are having (writing next to the solid stage written on the blackboard) the process of freezing then here we are having the process of melting (writing melting next to Liquid stage) its melts then once it becomes to this stage (pointing at melting written of blackboard) particles are no more closely packed as they were before, the reason why at the solid state it was the ice it's because the particles were closely packed, there were no spaces in between, they couldn't move, they couldn't move okay stand up (asking two students to stand up) it's a pity they cannot be water they are human beings, they are human beings but once they are the ice (putting students closely to each other as they lean against each other's backs) they are like this (demonstrating these two students as pressed together against each other to show closeness), can you see then once there is heating or warmth, they become there is a small space in between (slowly separating the students who are leaning closely against each other to show little space as ice is heated) so the melting process takes place.*	**Learners' role:** A learner responded that the reason the ice which teacher brought to class was changing into liquid water was that it has melted (LP). **Teacher Amanda's role:** The teacher confirms learner knowledge and she repeat the learner response and further expand it stating that the physical process-taking place is called melting. The teacher is using real life examples to foster understanding as she makes examples such as melting of candle wax. Furthermore, teacher Amanda is demonstrating the concept of particles at solid stage (closely packed) using students to demonstrate the concept of spaces between particles of solids and liquids. In this demonstration teacher, is drawing from her knowledge of microscopic representation **(RP)** of matter in solid and liquid phase. Teacher Amanda is also using her knowledge of representations **(RP)** interactively to illustrate the effect of temperature on particles as temperatures increases thereby causing phase change through melting process. Teacher Amanda starts explaining with macroscopic explanations while relating the concept with learners' day to day life experiences. The teacher further uses the particulate explanations to explain what happens at a microscopic level during solid phase of matter by stating that in solid phase or ice particles are closely packed. The lesson further explains to learners that in order to achieve this state of matter, temperatures become a critical variable from which the physical changes of matter depend upon **(CS).** Teacher Amanda explains further that if for example ice water is taken out of freeze, the physical process taking place is called melting. In the discussion above, LP-RP/CS were used interactively to design The TSPCK Map for the above discussion is given below: 

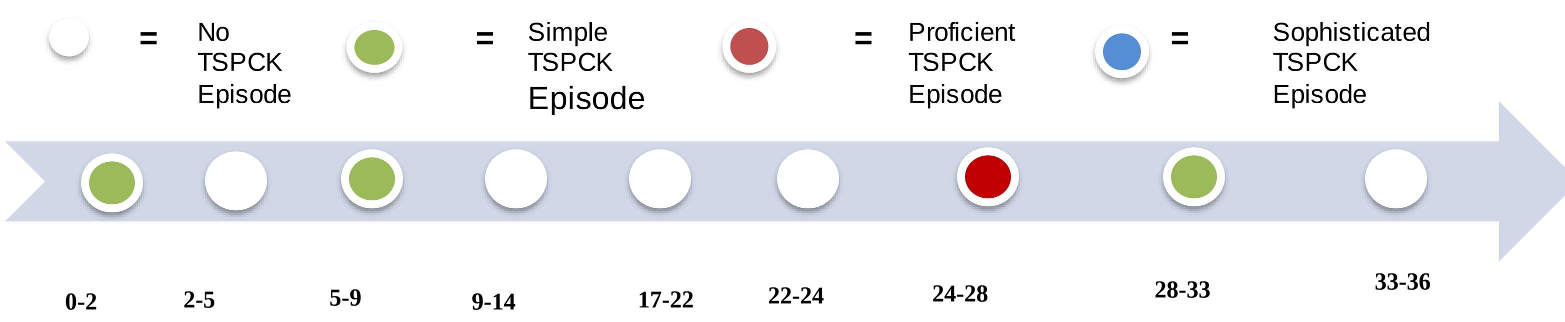
21:37-23:35min: Consolidation of three phases of matter *I think now we need to go to the kitchen so that we observe that after melting if we have heated the water what are we going to see, can Pretty quickly go to the kitchen and ask the aunties if they have boiled the water so that we can come and observe okay ehhhhhhhhh meanwhile can you ask me some questions, can you ask me some questions can you ask me some questions, okay you don't have questions, how many phases of water do we have, hands up, how many phases of water do we have of or how many phases of matter do we have ohhh ndizoteacher abantu abanye apha (a Xhosa sentence which means I came to teach only few people here?)oh I am only teaching few selected people here), yes Njikelana* *Learner: We have … (mumbling)* *Teacher: Again (teacher guiding learner to say what she has written on the blackboard by pointing out at phases of matter written on the blackboard)* *Learner: We have three phases of matter* *Teacher: Class (showing three fingers)* *Class: We have three phases of matter* *Teacher (expecting learners to also show three fingers as she does) oooh niqhawukelwe yiminwe i-integration aniyazi? (ooh your fingers are cut off you don't know integration)* *Class: (showing three fingers) we have three phases of matter* *Techer: what are they? The first one (pointing at solid state written on blackboard)* *Class (singing): solid stage* *Teacher (showing up the second finger) the second one?* *Learners: Liquid stage* *Techer: (showing up the third finger) the third on?* *Class: Mumbling* *Teacher: Come again* *Learners: Gas stage* *Teacher: Writing on the blackboard: it's a gaseous stage, the one you are going to observe from the kitchen (writing next to gaseous phase) and we said this one we will be having water vapor,*	**Comment:** In this section the teacher Amanda is consolidating the three states of matter and is orally assessing learner understanding so far **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's role:** The teacher asked learners the number of phases the different phases of matter and further asked learners to name these phases one by one. The teacher is therefore having a reflection session with students before proceeding with the lesson while strategically emphasizing the concepts covered. **Leaners' role:** Learners responded that there were three phases of matter, solid stage, and liquid stage. When learners were naming the third phases of matter they said it was gas phase contrary to the "gaseous phase" which is a widely accepted term to refer to the gas phase No TSPCK as the teacher is helping learners to understand scientific language.
23:35-28:11min: Describing Gaseous Stage *I have got a question, can we touch the water vapor, hands up? Okay before I go to that question, can we touch the ice, can we touch the ice* *Class: yes* *Teacher: Can we touch the ice* *Class: Yes* *Teacher: Can we touch the water?* *Class: Yes* *Teacher: Can we touch the water vapor?* *Class: No* *Teacher: Why?* *Learner: Mumbling* *Teacher: You are not telling me you are telling the class stand up, you are telling me* *Learner: Because it is a gas* *Teacher: Then can you elaborate or can you explain why we cannot touch a gas? What is air made up of? (That is Grade 4 work) air is*	**Comment:** In this discussion teacher Amanda is gaseous phase to the learners **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's role:** Teacher Amanda is asking learners if it is possible to touch water vapor. In guiding the conceptual understanding of learners teacher Amanda is using the liquid and solid stage and compares the tangibility of these two with gases. **Learners' Role:** Learners responded that yes you can touch the ice (solids) and can touch the water (liquid) and No you cannot touch the water vapor because it is a gas **Teacher Amanda's Role:** As learners responded that water vapor is a gas, the teacher then used the example of air to

made up of (writing on blackboard) what is an air made up of? Air is made up of, class? *Class: Mumbling* *Teacher: Hay mandingagqityezelelwa, andiniva futhi noba nithini, air is made up of?* *Class: Air is made up of …. (mumbling)* *Teacher: Of what?* *Class: Air is made up of …. (mumbling)* *Teacher: Come again (pointing at one group where it seems like they are mumbling something close to the answer that the teachers is looking for)* *Class: Air is made up of …. (mumbling)* *Teacher: (writing on blackboard) air is made up of different gases, if I can ask you one by one, (interrupted by the student who is coming from the kitchen as sent by the teacher then responding with okay)….(recapping for the student she sent away to the kitchen) meanwhile you were in the kitchen Pretty I said, can you touch the ice (Pretty responding yes Miss), ehh can you touch the water, Pretty responding Yes Miss, can you touch the water vapor, Pretty no Miss)* *Teacher: Why? Why? Why you cannot touch the water vapor? It's because the water vapor is a (pointing at the word 'gases' written on blackboard)* *Class: (finishing the sentence for teacher) the gas* *Teacher: and we cannot touch the ……* *Class (finishing together with teacher) the gas* *Teacher: Okay ehhh can I ask eeeeh all of you eeh just bring me some gas or bring me some air, bring me some air, can you please bring me some air?* *Learner: Oxygen air* *Teacher: You are giving me the example I am saying take it and give it to me, that's very good he was giving me the example, don't laugh he is giving me an example, oxygen is an example of the air of the gas, I am saying can you please take some air and give it to me or take some gas and give it to me, I don't understand you can you please do that for me, can you take some gas and give it to me* *Class; no* *Teacher: Why? Yes, Mpako why?* *Learner: because the gas is untouchable* *Teacher: clapping hands once due to excitement: very good class the gas is….* *Class (finishing after the teacher): untouchable* *Teacher: you cannot touch you cannot show me that this is air although air is around us but when I am saying take some air and give it to me you cannot do that but at the same time you cannot say this glass (showing to the whole class an empty glass beaker) is empty, do you think this glass is empty? Do you think this glass is empty?* *Class: Mumbling* *Teacher: What is full here (pointing at an empty glass beaker) what is inside this eeeh glass* *Class: Air* *Teacher: This glass is full of air, this glass is not empty, its full of gas but when I am saying bring it to me you cannot, you cannot*	explain that air was made up of different gases and further asked learners why it was not possible to touch gases. **Learners' Role:** A learner responded that it was not possible to touch gases because gases are untouchable **Teacher Amanda's Role:** Teacher Amanda further emphasizes that while the air is around us but it was not possible to touch it, it was not possible to bring someone air even though everything around us was full of air. The teacher used an empty glass beaker and further explained to learners that even though the glass looked as if it was empty but there was air inside filling the glass. The lesson does not however address the particulate explanation of matter except long questions which seek to develop scientific terminology for various phenomena happening at home No TSPCK episode

28:11-32:44min: Describing Effect of Temperatures on Phases of Matter *Teacher: Okay now we are saying once the liquid is……what happens to liquid stage up until it reaches this stage the gaseous stage what must we do what must we do, here we said the solid stage the ice it must be (pointing at the blackboard on the notes where she wrote freezes)…in the freezer so that it freezes then the process its freezing (class repeating and singing with teacher as she points on the blackboard notes) then for the liquid stage we said we have got an example of water whereby it defrozes from the ice and its melts and the process is melting then my question is: when you are taking this water and you want to see the water vapor, what must you do? So many hands now (seeing a number of students raising up their hands) some other Grade 8 are hiding themselves why? Why? Why? Yes Mpunge (pointing at a student) what must we do?* *Learner: boil the water* *Teacher: Very good, class what must we do to the water if we want to see the water vapour* *Class: we must boil the water* *Teacher: The water must be boiled, boils and the process its boiling (writing on bb) once you are boiling or once you are heating you heat then process its heating then when we talk about water vapor it depends all these stages they depend on the temperatures if you put the water in the freezer and the temperatures of the freezer are very low they won't freeze do you get me* *Class: Yes* *Teacher: All these stages of matter they depend on the temperatures they depend on the temperatures on the….* *Class: temperatures,* *Teacher: that means we've got what is called the variables (noting variables on the blackboard) that means we've got what is called the variables…something which can happen because there is something when we are talking about the variables you are mentioning something which makes something to happen, do you get me that means there should be variables, one of the variables should be the temperature, if the temperatures of the freezer are not high they cannot freeze, you can put them for so many hours when you go and check, you'll find that the temperatures are very low…they won't freeze and still if you are in the classroom or you have taken your ice outside and the weather is the temperatures are very eeeeh cold like today you will find the ice, if this the ice is too much it won't defroze then even the water if you want to see the water vapor if you are heating it and your heat you are using is not too much that water cannot boil as a result you will not see the water vapor that means that variable of the temperatures is very much important in the stages of matter then the most simple example of the stages of matter its water if you really want to understand the stages of matter you must always use water another reason is that water is a natural resource, water is a….* *Class: Singing together with the teacher: natural resource*	**Comment:** In this discussion teacher Amanda is introducing to the learners the effect of temperatures in the three phases of matter **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda' Role**: Teacher Amanda asked learners what they must do in order for liquid water to change into water vapor. **Learners' Role:** A learner responded that the we must boil the water (LP) **Teacher Amanda's Role:** The teacher confirms to the student that indeed water will have to be boiled to get water vapor and further expand this phenomenon as she stated that once you are boiling you are heating and added that all the three phases of matter depended on temperatures, the teacher then took each phase and explained that if the temperatures were not favoring the transition to another phase and spoke about low and high temperature**.** The teacher then conclude that temperatures were a variable which change on phase depended upon. In this teaching segment, it can be concluded that teacher Amanda is using the LP-CS to explain to learners the effect of temperatures during phase change. Thus, the resulting TSPCK episode can be mapped as follows: 
32:44-36:01: Explaining the physical properties of solids in terms of shape *Teacher: Does the ice have a shape (quite) and a size? Does the ice have a shape and a size? Does the ice have a shape and a size? Simple thing… Okay let me start this question. If I've taken*	**Comment**: In the teacher Amanda introduces learners to the fact that the ice takes the shape of the container **<u>In-depth Qualitative analysis:</u>**

this bottle of water to the freezer, what shape of my ice will I have? If I've taken this water bottle to the freezer what shape of my ice will I have? Simple question! If I take this water to the freezer what will be the shape and the size of my ice? Yes Benni? *Benni: The ice takes the shape of the container.* *Teacher: Simple and straight forward, it takes the shape of the container. Class?* *Class: It takes the shape of the container. It takes the shape of the container!* *Teacher: It takes the shape and size the size…. very good Benni. If I 've taken this tube because in mathematic we call it a tube. If I've taken this tube and poured some water and put it in the freezer my ice will be the tube shape and the size will be of the tube is it? Do you agree with me?* *Class: Yes* *Teacher: So the ice takes the shape and the size of the container.*	**Teacher's role**: In the discussion above, firstly the correct concept is that liquids take the shape of the container, however teacher Amanda uses the example of ice and conclude that ice (solids) take the shape of the container. This is not correct; ice does not take the shape of the container. Due to misconception from the teacher about liquids and solids taking the shape of the container, the framework of TSPCK takes content understanding seriously as pre-requisite to building up PCK and by inference TSPCK. Therefore, a teaching segment with wrong content knowledge cannot be analysed for any emergence of TSPCK components.

The video transcripts reveal the language difficulties of both the teacher and students. Both lessons are evidence of the suggestions that the quality of teaching in the Eastern Cape is poor due to the background of teachers which is poor in terms of content. To provide an overview of teacher Amanda's lesson prior the intervention, the sequence of the TSPCK episodes that emerged during her lessons were summarised as given in Figure 7.1 to produce a teacher pictorial representation of teacher Amanda's teaching profile.



Total Simple TSPCK Episodes = 3 Total Proficient TSPCK Episodes = 1 Total Sophisticated TSPCK Episodes = 0

Figure 7.1: Amanda's teaching profile for pre-intervention lesson 1

The rubric that was designed and validated in a study by Miheso (2018) has three types of TSPCK episodes as pre-determined categories corresponding to the quality of eTSPCK. However, to capture every teaching segment, those teaching segments that only showed one TSPCK component not interacting with any other components were categorized as No TSPCK episode. A simple TSPCK episode meant that the teaching segment had two different TSPCK components interacting evidently and distinguishably in a specific teacher task segment and the interactions were either interwoven or linear. The components were also working together to explain either one or a pair of related concepts.

A proficient TSPCK episode meant three different TSPCK components interacting evidently and distinguishably in a specific teacher task segment. It could also be that the three different TSPCK components were interacting, evidently, and distinguishably in a specific teacher task segment, but one component repeating and bringing a different level of explanation that complements the initial emergence. Additionally, the TSPCK component interactions could be interwoven or have a linear sequence structural formation or both and the three components work together to support an explanation of a single or a pair of concepts that are related.

A sophisticated TSPCK episode meant that four different TSPCK components were interacting evidently and distinguishably in a specific teacher task segment or four different TSPCK components were interacting evidently and distinguishably in a specific teacher task segment, with one of the components repeated more than once or one of the components bringing different levels of sophistication (e.g. representations used at macro, symbolic and submicroscopic levels.) TSPCK component interactions could be interwoven or have a linear sequence structural formation or both. All the TSPCK components were working together to support an explanation of a single or a pair of concepts that are related.

As indicated in Figure 7.1 teacher Amanda's lessons mostly consisted of simple TSPCK episodes as indicated by (n=3) in lesson 1 and (n=4) in lesson 2 as given in Figure 7.1 which sum up to 7 simple TSPCK episodes prior the intervention. The simple TSPCK episodes were followed by proficient TSPCK episodes, as there was only one of this kind of episode in both lesson one and lesson two. There were no sophisticated TSPCK episodes in teacher Amanda's explanations of the particulate nature of matter.

In conclusion, in the pre-lessons, the teacher used common knowledge to explain matter and was using day-to-day experiences such as boiling water, ice water, melting wax and other examples. The lesson could not align any of these home-based scenarios with the curriculum concepts of the model of the particulate nature of matter. While the model of the particulate nature of matter constitutes the teaching of this topic, one of the main deficiencies in teacher Amanda's explanations were interpretations of matter from particle level of understanding and prescribed curriculum. Thus, failed to relate the different materials identified with the three phases to the model of the particulate nature of matter. The lesson was concluded with a common observation of the difference between a refrigerator and a deep freezer that the teacher referred to as an experiment but again with little or no reference to the model of the particulate nature of matter. As it is evidenced in the table of analysis above, the lesson by teacher Amanda remained a collection of question and answer method that only focused on probing and scaffolding learners' scientific language in naming phenomena such as *"smoke coming out of boiling water"* and helping students to call such 'water vapor' or gas phase. In some cases, the teacher had the concepts taught incorrectly, for example in one instance when explaining the concept of boiling water changing into water vapor, the teacher explained the phenomenon as though water disappeared. Wightman, Green, & Scott, (1986) defined "disappearance" as one of the most common learner misconceptions that students have around this phenomenon of transition from the liquid phase to water vapour.

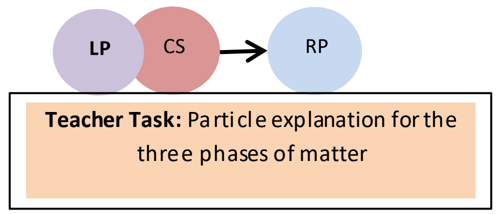
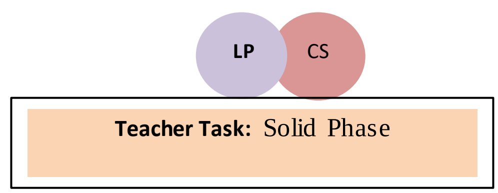
Case 1: Teacher Amanda's post-intervention lessons on Phases of Matter and Change of State

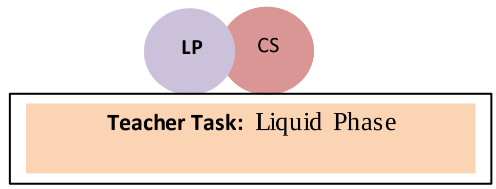
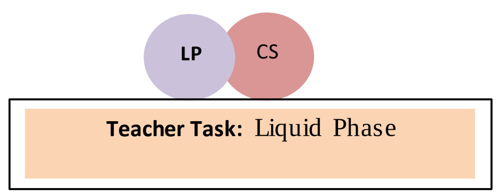
(i) Overview description of the post-intervention lessons

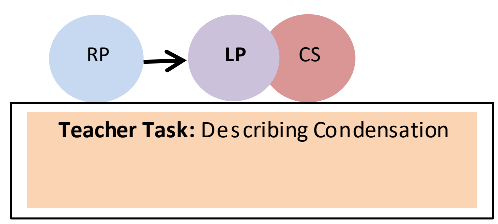
Key to the construct of the collective TSPCK is the possibility of fast-tracking the development of pre-service teachers' knowledge needed for the pedagogical transformation of content into little bits that learners can easily understand. In this study, the construct was used to fast track the development of the OFTs' TSPCK in the topic of particulate nature of matter. There was an improvement in how the OFTs structured their explanations post the intervention. The teacher explanations formulated post the intervention were more aligned with the model of the particulate nature of matter compared to the pre-intervention lessons which had fewer explanations of matter at the particulate level.

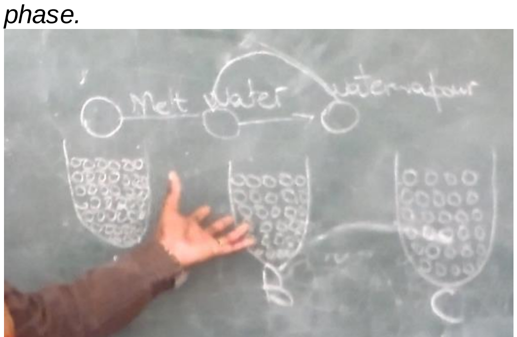
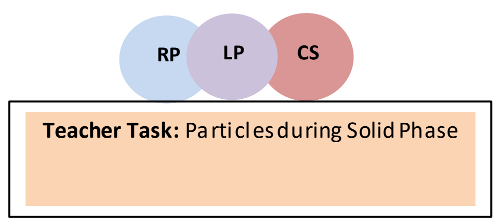
Table 7. 4: in-depth analysis for teacher Amanda's post-intervention lesson 1

Lesson 1	
Extracts of Amanda's teaching in sequence	Comments/Qualitative in-depth analysis
<u>0-4:52 min: Describing Matter</u> *Teacher Amanda: Good morning once more* *Class: Mumbles* *Teacher Amanda: Good morning, thank you sit down.* *We are going to talk about the 3 phases of matter. Before we talk about the 3 phases, who can remind me what is a Matter? Yes Merriam, come again I cannot hear you, they are making a noise. Please raise up your voice.* *Class: Matter is anything that occupies space which has mas or weight.* *Teacher Amanda asks class, what is matter?* *Class: Matter is anything that occupies space around us (which has mass or weight)* *Teacher Amanda: Let's take an example of water as a matter because we said anything that occupies space is it? Let us take water because water is a natural source is it, so that it can be easy for us to understand when we talk about water.* *Who can give me, what are the 3 phases of matter?* *Class: mumbles* *Teacher Amanda: I said raise up your hand, the 3 phases of matter or the 3 states of matter (writing on the board). What are the 3 states or matter or what are the 3 phases of matter.* *Class: The 3 phases of matter are Solids, Liquids and Gaseous.* *Teacher Amanda: Very good. Class, the 3 phases of matter are Solids, Liquids and Gaseous. Class?!* *Class: The 3 phases of matter are Solids…(mumbles)* *Teacher Amanda: Class, the 3 phases of matter are.* *Class: The 3 phases of matter are Solid, Liquid and Gaseous.* *Okay, what is matter made up off? What is matter made up off? What is matter made up off? You remember the other day when I was talking about density, I even made an example about the*	**Comment:** In the teaching segment above, teacher Amanda is explaining Matter to learners. **Teacher Amanda's Role:** The teacher explained to learners that the lesson was going to be on the three phases of matter and immediately asked learners what is matter before the lesson could start. **Learners' Role:** the learners responded that matter is anything that occupies mass and has mass and therefore revealing their learner prior knowledge about the concept (LP) **Teachers' Role:** The teacher then affirmed the learners' response by repeating the definition learners gave and further asked learners that they take water as example of matter (RP). The teacher then asked learners to give her three phases of matter **Learners' Role:** The learners responded that there were solids, liquids and gases **Teacher Amanda's Role:** The teacher further asked learners what matter was made up of. **Learners' Role**: The learners kept mumbling **Teacher Amanda's Role:** The teacher then explained to learners that by explaining to learners that matter was made up of tiny particles and thus aligning the definition of matter to the particulate model of matter as matter as she consolidated the session by stating "*It is made up of tiny…. it is made up of tiny particles"* It is evident from the discussion above that teacher Amanda is using three components of TSPCK to explain the concept of matter to learners and these that are **LP/CS-RP.** The

cork and the duster? It is made up off? It is made up off? What is it made up off? *Class: Mumbles* *Teacher Amanda: Why are you so lost? It is made up of? What is it?* *Class: mumbles* *Teacher Amanda: Come again. It is made up of tiny…* *Class: mumbles* *Teacher Amanda: come again. It is made up of tiny, it is made up of tiny particles. Class?* *Class: It is made up of tiny particles* *Teacher Amanda: It is made up of tiny particles* *Class: It is made up of tiny particles*	TSPCK Episode identified can be mapped as presented in the following diagram: 
<u>04:52 -06:08 min: Describing Solid Phase</u> *Teacher Amanda: Are the particles arranged in the same when talking about the 3 phases of matter? Are the particles arranged the same way if for instance you talk about, make an example of water? If you take water and put it in the freezer, what happens? Yes Mirriam! What happens if you take water and you put it in the freezer, what happens? We went to the staff room to see what happens. I even brought some.* *Class: you put it in the refrigerator* *Teacher Amanda: Come again, I know that we put it in the refrigerator but my question is, what happens when take water and put it in the freezer. Yes* *Class: the water freezes and it turns into ice.* *Teacher Amanda, Very good. When you take water and put it in the freezer, the water freezes and becomes ice.*	**Comment:** In this section the teacher is introducing her learners to a concept of different particle arrangement for three phases of matter **Teacher Amanda's Role:** The teacher asked learners if the particles were arranged in the same way in the three phases of matter. In guiding construction of learners understanding, the teacher broke down her question into focusing on one phase of matter. The teacher then asked learners to make an example of putting liquid water into a refrigerator and asked learners what happens to the liquid water. **Learners' Role**: The learner responded that water would freeze and become ice **Teacher Amanda's Role**: The teacher then confirmed the learner statement as correct. In this episode, there are two components of TSPCK used and these are LP/CS. The corresponding TSPCK Map to this episode can be given as the teacher 
<u>06:08 -07:58 min: Describing Liquid Phase</u> *Teacher: The same ice if you take that ice and put it on an open space, you put it on an open space, you take it out from the freezer, you put it in a plate or in a glass, what happens. You take the same ice, which is, we that it is water but because it is there in the freezer, it freezes then you take out from the freezer and you put it on an open space then whereby the temperatures are different from the temperatures of the fridge freezer and you just put it here in the classroom, what happens to that water (ice)? What happens if you take the same ice, you take it away from the freezer, you put it in a plate and you bring it in the classroom, whereby the temperatures are totally different from the temperatures of the freezer, what would happen to that water/ to that ice?* *Class: The ice will turn into water.* *Teacher Amanda: The ice will become water but I want what is happening when the ice is becoming water? What is*	**Comment:** The teacher continues to lay foundation into allowing learners to construct their knowledge of particle arrangement in Liquid Phase **Teacher Amanda's Role:** The teacher then continued to now talk about Liquid phase as she asked learners what happens when you take the ice outside the freezer, the temperature explained that taking out the ice from fridge meant taking ice to different temperatures and specifically used room temperature as different from Fridge temperatures. **Learners' Role:** Learners responded that the ice would become water (liquid) **Teacher Amanda's Role:** The teacher then guides learners to respond along the lines of describing this phenomenon through the process that causes ice to become water as she agreed to the learners' response that the ice will become water but further asked what happens when the ice becomes water.

happening? What is happening? M, the word starts with M. What happens? Yes Mapaka *Class: The ice melts* *Teacher Amanda: The ice melts, the ice melts and becomes water. The ice melts and becomes water.*	**Learner Response**: The learner responded that ice melts **Teacher Amanda's Role:** The teacher confirmed the response by this learner as correct as she repeated that the ice melts and becomes water In the TSPCK episode above, the teacher is using knowledge of LP/CS interactively to take learners through Liquid phase and uses the physical process to describe how these are interpreted at a macroscopic level. The resulting TSPCK Map for the above discussed episode is given as follows: 
<u>07:58 -10:20 min: Describing Gaseous Phase</u> *Okay you take that water now, in the liquid phase of state then you put it in the kettle or in a pot and you boil it, you boil the water. What are you expecting from that water? What are we expecting from that water? Now we have taken the water, poured on to the kettle, or pot or glass beaker, if we were having a science kit and you take a Bunsen burner to heat the water, you are heating the water, what will happen? What are we going to see, what will happen? YES.* *Class: You are going to see evaporation.* *Teacher Amanda: No No No, thank you, you have tried. What would happen, what will happen? Yes* *Class: water vapor* *Teacher Amanda: Before we see the water vapor, he is talking about the water vapor, but what would happen, the vapor, what happens to that water. In order for us to see the water vapor, what can we do or what will happen to this water. Before we see the water vapor, there is some which will be done in the water, what is it?* *Class: The water will boil.* *Teacher Amanda: Very good. The water will boil. The water boils and we will see the water vapor in other words we will bring these three verbs (pointing at the black board at freezes, melts and boils). When it freezers it becomes ice, that is the solid stage. Then when you talk about the liquid stage, the water, the ice melts and becomes water. Then the same water is you boil it, it will give you the water vapor. (Pointing at the black board).*	**Comment**: In this discussion the teacher is explaining to learners what happens to liquids to reach gaseous phase **Teacher Amanda Role:** The teacher asked learners what happens to water when heated **Learners' Role:** Learners gave different responses but the teacher was interested on the process as she only took a learner response that stated that water will boil **Teacher Amanda's Role:** The teacher then consolidated the session by explaining to learners that they had to know the verbs which meant what happens to matter to change phase as she wrote that (freezes, melts and boils) next to solid, liquid and gaseous phase respectively. It can be deduced from the discussion above that teacher Amanda is using LP/CS to explain to learners. The resulting TSPCK Map for the episode discussed above is provided below: 
<u>10:20- 11:33 min: Describing Evaporation</u> *Then if you keep on boiling the water, what will happen again, if you keep on boiling the water. You boil the water, you boil the water, you boil the water, afterwards, if for instance you have added more temperature or some more heat. Let us say you are having the gas stove as we did that day and you boil this water, you boil this water and you boil this water. After some time when you look at this water, do you think you will see that water? The water won't be there. That means the water has evaporated then we say the process is evaporation. The water*	**Comment:** In this discussion the teacher is explaining to learners what learners would observe at a macroscopic level when water is boiled further beyond boiling point. **Teacher Amanda's Role:** The teacher explained to learners that as the effect of temperatures was raised beyond boiling point the matter (water) would change form into gas. The teacher also poses a potential confusion of boiling and evaporation.

vapor (writing in the black board) and the process is evaporation.	This teaching segment does not fit any of the categories of TSPCK episode therefore there is no TSPCK episode
11:33-14:50min**: **Describing Condensation ***Teacher:** Okay, then we are heating this water and we take the water against the wall so that we can be easily see that water vapor clearly (walking towards the wall and pointing at the wall). Let us say we have got the gas stove here and the water boils and that water vapor is coming straight to the wall, when, when the water vapor is coming straight to the wall the temperature again of the water, of the wall is totally different from the stove. What will happen? When the water vapor is coming to the wall. What will happen then, what can you see? What can you see. Yes Merriam (Teacher pointing at the water, demonstrating the water vapor)* *Class: We will see water* *Teacher Amanda: We will see the drops of water. The reason why, is because the water vapor was having a certain temperature but once it heats the wall it comes and meet another temperature which is totally different from the heat then it cools down and the water vapor becomes the drops of water and what is happening there we say the water vapor condenses and what is the process? If we are saying it condenses what is the process (repeat) the process is condensation (repeat) the water vapor condenses in other words if for instance we can draw something we will be having ice here and it will melt and becomes water and this stage and you heat it up until you have got the water vapor here but the same water vapor will go back and becomes water you have got the ice and once it's out of the freezer it will melt and becomes water then you heat it again until you have got the water vapor then once the water vapor is eeeeh having another temperature again that means there is something which happening the temperatures the temperatures they play a very big role to give us the different stages of water , do you get me* *Class: Yes Miss* *Teacher: Do you understand* *Class: Mumbling* *Teacher: Do you understand* *Class: Yes*	**Comment**: In this discussion, the teacher is explaining the concept of condensation. **Teacher Amanda's Role:** In this discussion the teacher gave learners a demonstration of a water vapor rising up from boiling water meeting cold temperatures of the wall next to the stove, the teacher asked learners what would happen when this phenomenon happens. In this demonstration the teacher is using a real-life analogy which learners are familiar with at a macroscopic level (RP) **Learners' Role:** A learner responded that they would observe water drops (LP) **Teachers' Role:** The teacher added value to the learner response as she specifically mentioned that the learners would observe not just water but droplets. The teacher then explained that the reason beyond this phenomenon was that the cold temperatures from the wall met high temperatures from water vapor causing condensation process (CS) In this episode, the teacher is using three components of TSPCK to RP-LP/CS to explain the phenomenon of condensation. The teacher starts from learners' general knowledge and observations to lay foundations for teaching them the correct scientific knowledge which explains the process of condensation 
<u>14:56-17:22 min: Revising the three States of Matter</u> *Andrews why are you playing) Andrews what are the three stages of water, what are the three stages of matter? Class what are the three stages of matter hands up, what are the three stages of matter, hands up, what are the three stages or what are the three phases of water, hands up, this is a revision of what we did just now, what are the three phases of water, Yes Pretty* *Learner: Solids, Liquids and gases* *Teacher: Very good, Class? The Three phases of water are. (15:50). Class, the three phases of water are? (Teacher drawing on the black board, a three-part demonstration drawing). Class, what are the three phases of water?* *Class: The three phases of water is.* *Teacher Amanda: three phases of water "are" a singular, noun, tense, and a singular verb. Then a plural, noun, takes a plural verb. The three phases of water are, class*	**Comment:** In this teaching segment, the teacher is helping the learners to recall the three phases of matter.

Class: the three phases of water are solids, liquids and gas *some gases mumbling* *Teacher Amanda: Again* *Class: the three phases of water are solids, liquids and gases* *Teacher Amanda: the three phases of water of water are?* *Class: the three phases of water are solids, liquids and gases* *Teacher: Again…………………*	
17:24-18:27 min: Describing Solid Phase using Particle Model of Matter *Okay (pointing at the black board with the three demonstration boards.) Let us say these are our beakers. Let us say that these are our beakers, glass beakers, or our glasses. Who can tell me, lets us say this is A, this is B and this is C. Who can tell which one represents the solid phase? Who can tell which one represents the solid phase? We have got these three beakers, who can tell me which one represents the solid phase, where the particles are closely packed. Which one represents the solid phase.*  *Learner: Glass Beaker A* *Teacher Amanda: glass beaker A represents the sold phase. Very good because You can see that the particles are closely packed.*	**Comment**: In this teaching segment the teacher is introducing to the learners the concept of particle concept underlying the phases of matter which even though the drawing is not correct however the explanations for each of the phenomenon were correct and this was the key aspect considered for this teaching segment. **Teacher Amanda's Role:** The teacher introduced to learners conceptual representations of three glass beakers and labelled them A B and C (RP). The teacher asked learners the beaker that represented solid phase. **Learner's Role:** The learners responded that the first glass beaker represented solid phase (LP) **Teacher Amanda's Role:** The teacher explained then explained to learners that particles in glass beaker A were closely packed together. As compared to the lessons prior the intervention, teacher Amanda's explanation is quickly directed to particle nature of matter rather than only explaining concepts from macroscopic level. The teacher started by moving from the macroscopic processes she gave in the previous segments into sub-microscopic explanations using representations to demonstrate particle arrangement during solid phase (RP) In The sequence of the components RP/LP/CS in the TSPCK episode above can be mapped as follows: 
18:27- 19:14 min: Describing Gaseous and Liquid Phase using Particle Model of Matter	**Comment**: In this teaching segment the teacher is describing the gaseous phase using particle explanations **Teacher Amanda's Role:** The teacher further moved to the second glass beaker and asked learners the beaker, which represented gaseous phase. The teacher further gave a hint that the glass which represented gaseous phase would have more spaces [between particles] (RP) **Learners' Role:** Learners responded that glass beaker C represented gaseous phase (LP)

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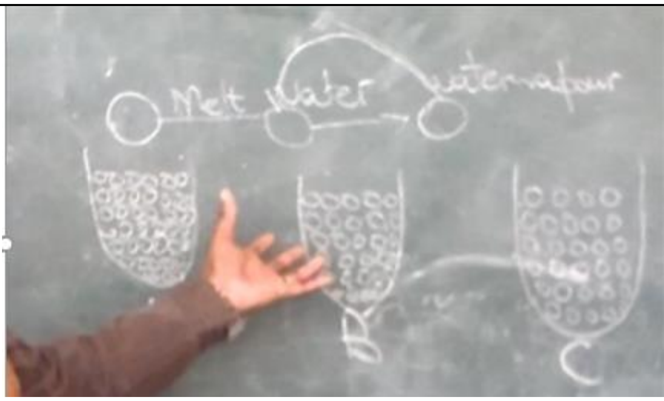
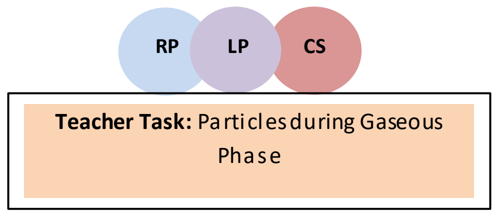
<td>
Which one represents the gaseous phase. Which one represents the gaseous phase, whereby there are spaces are more. Njikelana, is your up hand? Which one represents the gaseous phase, Yes Merriam. (Three glasses were drawn on the black board representing the different phases and the different particle structures.) Class: Glass beaker C represents the gaseous.
Teacher Amanda: Very good. Glass beaker C represents the gaseous phase because the particles now they have more space than the first and the second one. Which one represents the liquid phase? Which glass beaker represents the liquid phase? Yes.
Class: Glass B
Teacher Amanda: Glass beaker B represents the liquid phase</td>
<td>Teacher Amanda's Role: The teacher then confirmed the learner response and further explained that glass beaker C was gaseous phase because it had bigger spaces between the particles. The teacher further asserted that the spaces between the particles of gaseous phase were bigger than those in glass beaker A (solid) and glass beaker B (liquid phase). The TSPCK episode depicted in this discussion reveals an interactive use of RP/LP/CS and the TSPCK Map for this episode is given as:
</td>
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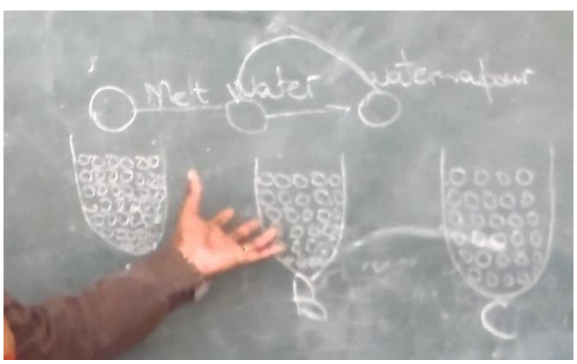
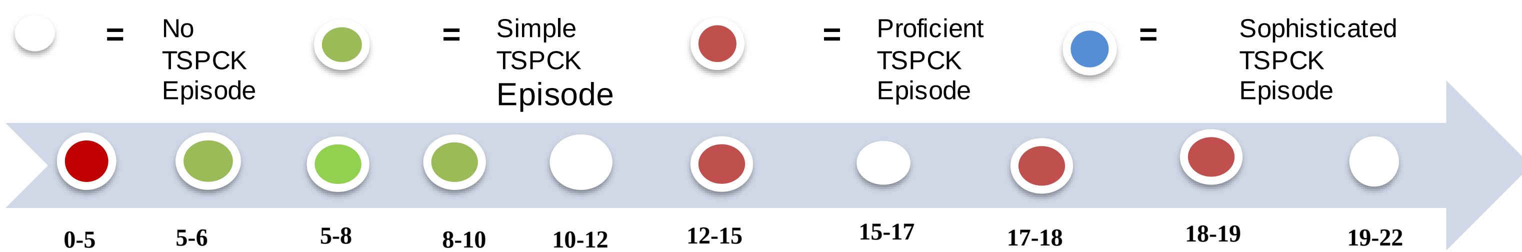
<td><u>19:14-21:31min: Describing the three phases of Matter using Particle Model of Matter</u>

Class, glass A represents hayi kalok, andizoni gqhibezelela (Xhosa word meaning I will not help you complete the sentence). Glass A?
Class: Glass A represents the… (mumbles)
Teacher Amanda: Come again?
Class: Glass A represents the…(mumbles)
Teacher Amanda: Again
Class: Glass A represents
Teacher Amanda: (On the cell phone) Mfundisi, (Xhosa word meaning teacher) alright.
(off the cell phone) Again, glass beaker A
Class: Glass beaker A represents solids
Teacher Amanda: (Pointing at the black board at glass beaker A)</td>
<td>Comment: In this teaching segment, the teacher is helping the learners to recall the three phases of matter. No TSPCK episode</td>
</tr>
</table>

Solid what? *Class: Glass beaker A represents solids* *Teacher Amanda: Again* *Class: Glass beaker A represents solids* *Teacher Amanda: Solid stage, its either you say stage or phase. Those three words they mean the same thing. Glass beaker A?* *Class: Glass beaker A represents solids stage* *Teacher Amanda: Glass beaker B (Pointing at the black board and glass beaker B)* *Class: Glass beaker A represents solid stage* *Teacher Amanda: Again* *Class: Glass beaker A represents solid stage* *Teacher Amanda: You can't even see that this is glass beaker B (while pointing at glass beaker B) this cannot be solid (while pointing at glass beaker B), this is liquid. This is solid (while pointing at glass beaker A). Glass beaker B?* *Class: Glass beaker B represents liquid stage* *Teacher Amanda: Again* *Class: Glass beaker B represents liquid stage* *Teacher Amanda: Glass beaker C? (while pointing at the black board at glass beaker C)* *Class: Glass beaker C represents gaseous stage*	

The sequence of the TSPCK episodes that emerged during teacher Amanda's lesson post the intervention were summarised in Figure 7.4 to produce a teacher pictorial representation and a summary of teacher Amanda's teaching profile post the intervention for lesson 1.

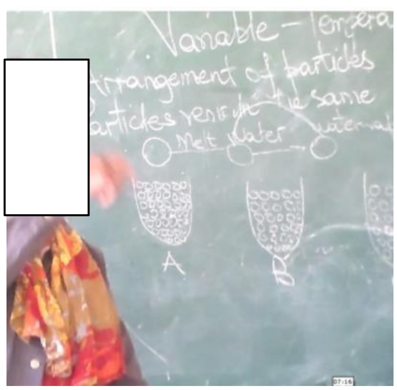
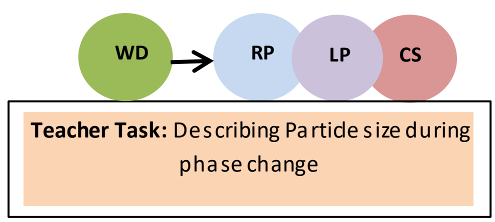


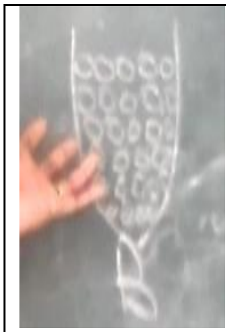
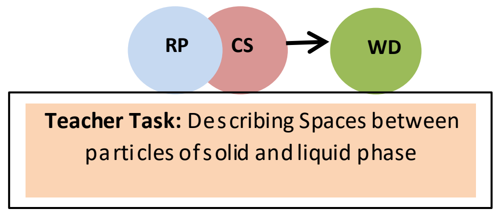
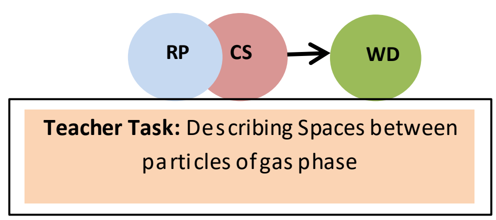
Total Simple TSPCK Episodes = 3 Total Proficient TSPCK Episodes = 4 Total Sophisticated TSPCK Episodes = 0

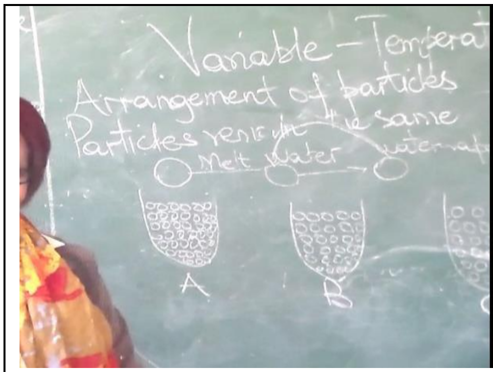
Figure 7.2: Amanda's teaching profile for post-intervention lesson 1

In lesson 1 post the intervention as given in the Figure 7.2, teacher Amanda had more proficient TSPCK episodes than simple TSPCK episodes. The total number of the episodes in both lessons is discussed at the end of in-depth analysis for lesson 2 after the intervention. In Table 7.5 given is the in-depth analysis for lesson 2.

Table 7. 5: In-depth analysis for teacher Amanda's post-intervention lesson 2

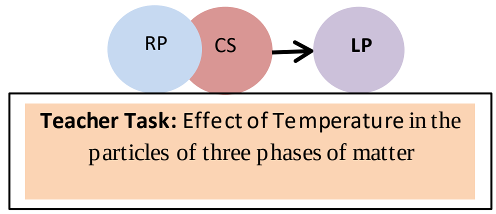
Lesson 2	
Extracts of Amanda's teaching in sequence	Comments/Qualitative in-depth analysis
<u>0- 3:22 min: Describing particle size during Phase change</u> *Teacher Amanda: Okay, I have a question now. Do the particles, do the particles change, do the particles, do the particles of matter change. Do the particles, if we were having water, were using particle of water, do they change, do they change the particles. Do the, do the particles change? Do the particles change? Do they change? Do they change? Do the particles change? Do the particles change? Just tell me just be innocent, just tell me. You think they change? Okay, are you trying to tell me when you were young, you were made up of the same cells then as you grow, you are made up of different cells, is it what you mean. If the particles change as something changes, is it changing from its originality? That is my question. Do the particles change if I have got water and I take it to the freezer, are you trying to tell me that if I am taking the water to the freezer, they are no more those particles? They have changed, is it what you are saying? Do the particles change? Come again* *Class: Yes* *Teacher Amanda: No, the particles do not change. The only thing that changes it is the spaces in between. The particles they do not change only the spaces in (teacher pointing at the black board between the different drawing A and B)* 	**Comment:** In this teaching segment teacher, the teacher is explaining to learners the particle size during phase change and thus addressing a concept that is difficult to teach in the topic of particle nature of matter. **Teacher Amanda's Role:** The teacher asked learners if particles change size as the teacher was guiding a probing learner knowledge about this concept she asked if during phase change "*is it changing from its originality That is my question". The teacher further explained her question as seen in this statement "Do the particles change (size) if I have got water and I take it to the freezer; are you trying to tell me that if I am taking the water to the freezer, they are no more those particles?"* **Learners 'Role:** The class though during phase change particle size of matter also changed as seen in their response "Yes" (LP) **Teacher Amanda's Role:** The teacher then used the diagram on the blackboard (RP) to explain to learners to learners that during phase change only spaces between particles changed but the same particles of water in all phases of matter remain the same particles (CS). In addition, teacher Amanda is also addressing the issue of what is difficult to teach indirectly (WD) through her use of representations as it is difficult to understand this concept without a visual aid which helps students to visualize the explanation given at a sub-microscopic level. In the TSPCK Episode above, four components were used interactively to explain the concept of particle arrangement during phase change.  The components were WD-RP/LP/CS thus this episode is categorized as that shows exemplary type of TSPCK Episode. The TSPCK Map for the following is:
<u>3:22-3:53min: Describing Spaces between particles of Solid and Liquid Phase</u> *You see, if for instance here (pointing at the black board at drawing B)*	**Comment:** In this discussion the teacher is explaining to learners phase change from solid phase to liquid phase **Teacher Amanda's Role:** In this teaching segment, the teacher explained to learners that in order for matter to make transition from glass beaker A (solid) to glass beaker B (liquid), the particles were heated. The teacher emphasizes the fact that while the particle composure remained the same and particles size does not change

 *we have applied heat. Obviously, here (pointing at the black board at drawing A) they not, they were freezing. So, they were closely packed. There was no space at all in between, but now they are having that heat, they are starting kicking one another. (pointing at drawing B) but they do not change, they remain the same.*	(WD) the difference in the two phases were that at glass beaker A the particles were closely packed together with little space or none between the particles and also indicated to learners that once heat applied the particles in beaker A started kicking one another. In this teaching segment, the teacher is using RP/CS-WD to explain to learners the concept of spaces between particles of solid stage compared to those of liquid phase. The use of TSPCK components in this episode can be mapped as follows: 
<u>3:53-5:58 min: Describing Spaces between particles of Gases</u> *When you heat them more to see the water vapor, the particles do not change (pointing at drawing C)*  *It's only the arrangement which is there. So, we must know that the particles of the matter doesn't change, it's only the rearrangement or the arrangement of particles which change. Do you get me? Do you get me?* *Class: Yes Miss.* *Teacher Amanda: Do you understand what I mean? Come here. Do you know Zoe, when he was do grade 4, he was slightly short, like this, slightly like this, but it was the same Zoe, I know him, I was teaching him. He was slightly short, as he was doing grade 5-6-7-8, can you see now where he is? But it is the same Adam. You cannot say he has changed. But it is only the arrangement of the cells. It's the arrangement of the cells. Otherwise, with the matter, the particles of matter doesn't change, but if we are talking about the different stages or the different phases, only the arrangement.*	**Comment:** In this discussion the teacher is explaining to learners the spaces between particles of gases Teacher Amanda's Role: The teacher picked her explanation from glass beaker B (liquid phase) and added that if the particles at this stage were further heated to see water vapor the particles still did not change (WD) but the arrangement of particles did change. The teacher compared the particle arrangement in the glass beaker B which was explained in the previous episode as representing particles which were sliding against each other but still close to each other and glass beaker C had more spaces in terms of particle arrangement (CS/RP) spaces in between. The emphasis was on the fact that spaces between particles were becoming bigger in liquids and bigger in gases. The teacher is using RP/CS-WD to explain to learners the concept of spaces between particles of gases by making a comparison with liquid phase. The use of TSPCK components in this episode can be mapped as follows: 
<u>5:58-07:32 min: Effect of temperatures in the particles of three phases of matter</u> *The other day I even mentioned that if you have used a variable, that if you have used a variable*	**Comment:** In this discussion the teacher is explaining the effect of temperature as a key variable in the change of the three phases of matter **Teacher Amanda's Role:** The teacher consolidated the discussions from the three previous episodes by explaining to learners that the temperatures affected the particle arrangement for each of the three phases she put on the blackboard (RP). The teacher used water as example of matter and had water going through the three phases of matter. The teacher then confronted the



A variable which is the temperature, in this case, it affects the arrangement of the particles. Once you have used a variable in this case, our example is water. It affects the arrangement of particles. Otherwise, the particles remain the same. So, if all along we were think that when we were talking about the phases, were thinking that they change the particles they change, they do not change. They remain the same only the arrangement which changes. Do you get me now? Do you understand me?

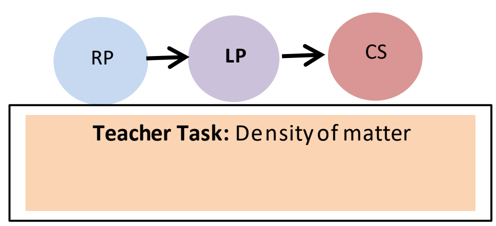
Learner misconception (LP) as she indicated that if learners thought during the change in the phases of matter particles size and particle nature changed these did not change but the manner in which spaces between particles of matter during each phase were the only thing that changed (CS).
The TSPCK episode described in this discussion portrays an interactive use of RP/CS-LP and the TSPCK Map for this episode is given as:

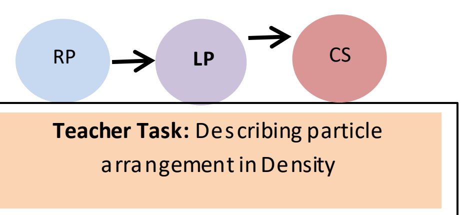


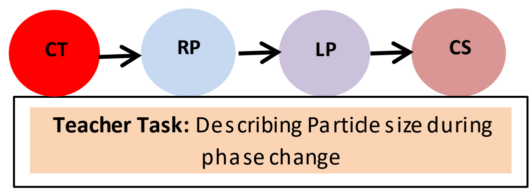
07:32-11:29min: Describing Gaseous and Liquid Phase using Particle Model of Matter

Okay, the other day, I think we are done with the phases matter. Let's go to the density. Do you still remember when I was talking about density? Do you still remember when I was talking about density? Who can remind me, what is density? I even gave you an example of a steel and a wood, I gave you an example of a steel and a wood, do you still remember that day
Class: Mumbles
Teacher: Which one is denser that the other if we are talking about steal and wood, which one is denser than the other one, for instance okay fortunately we do have these examples here (pointing at the steel part of the desk) what is this? Is an example of what?
Class: Steel
Teacher: (pointing at the wooden part of the desk) this is an example of what?
Class: A wood
Teacher: which one is denser than the other one
Class: Mumbles
Teacher: Come again
Class: Steal
Teacher: why do you say steal is denser than wood, why do you say so? X3
Class: Mumbles
Teacher: Come again, yes Merriam, try try say whatever you want to say?
Merriam: the steel is denser than wood
Teacher: why, the steel is denser than wood, good, why? If I can give you a piece of steel to break it, John, can you come here so that you break the steel, on the other hand Jack , you come here you try to break this wood, can you please do me a favor, you take this steel and break it then Jack you take this wood and you try to break it
Student Joseph & Zack: Trying to make some action as if they were trying to break these objects without success

Comment: In this teaching segment the teacher is introducing the concept of density in terms of particle nature of matter
Teacher Amanda's Role: The teacher asked learners to describe density and further gave them an example of wood and steel and asked them which of the two materials was denser than the other.
Learners' Role: Learners responded that steel was denser than the wood (LP)
Teacher Amanda's Role: The teacher further asked why is steel denser than wood, the teacher then made a demonstration (RP) where she two learners to the front of the class and illustrate that material which was easily breakable between wood and steel using the desk. The teacher then explained to learners that wood indeed break easily than steel. The teacher added that was a key variable in determining the increasing density of materials as she stated that if they were given enough energy the student with wood was going to able to break wood easier than steel while steel would take days and more time to break.
In this teaching segment, the teacher is using representations, analogies and demonstrations to teach learners about the concept of density. There were three components of TSPCK at play in this episode and were RP-LP-CS. The TSPCK Map for this episode is:

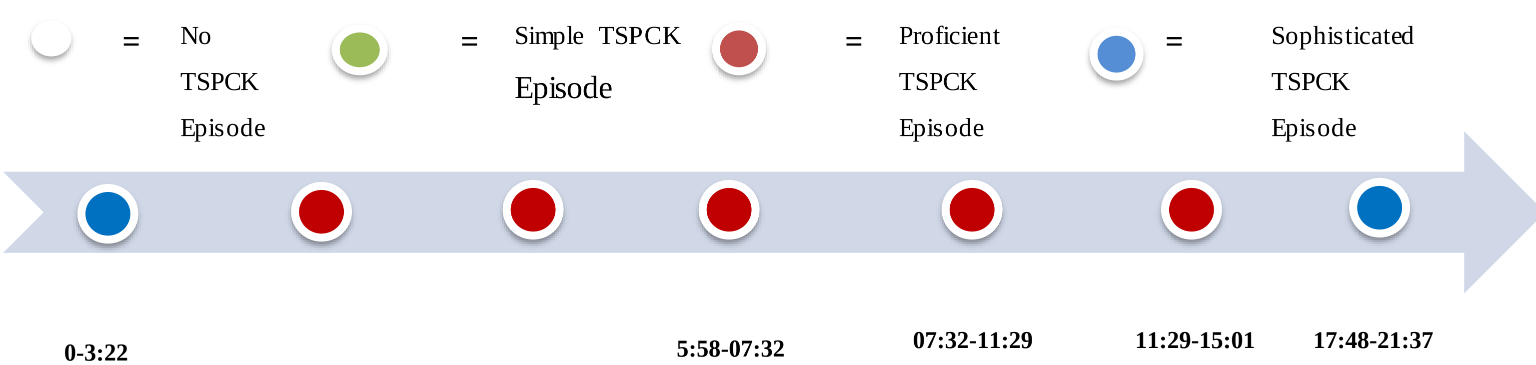


Teacher: Teacher no you have to do something I've said try to break this thing for me *Students: Trying harder with no success* *Teacher: But as you are trying okay they are no serious I can see because they are just using one hand, as you are trying if they were given enough energy, just tell me which one was going to be able to break the other from the two, I have got a wood for John I've got a…..I mean I ve got a steel for John I've got a wood for uLuzuko, let's say they were having enough energy, which one was going to be able to break his eeeeh matter* *Class: Zack (wood)* *Teacher: Zack was going to be able to break the. The wood then John was going to take too may be three days whereas Zack was going break it even today,*	
<u>11:29-15:01min: Describing Gaseous and Liquid Phase using Particle Model of Matter</u> *Teacher: why do you think like that and that is a very good thinking, why x3?* *Teacher; (takes a book and a paper) what is this class? (taking a folded paper and unfolds it as she asks the class) what is this?* *Class: Mumbles* *Teacher: (showing a book)* *Class: Mumbles (book)* *Teacher: if I can ask them (referring to the students who were standing in front of the class) fold this (reefing to the student with a paper) can you fold this quickly, just make it a small ball (REFERING TO STUDENT WITH A BOOK) CAN YOU please Fold this, make it small* *Students: Folding these two objects but the one with a book couldn't* *Teacher: Which one is denser than the other one, which one is denser you have got a paper you ve got a book which one has got …is more denser than the other one, this is a piece of paper and this is a book and the book is made up of…. …. paper. Which one is denser than the other one, which on is denser than the other one, Bangani?* *Student: The book* *Teacher: A book is more denser than a piece of the paper, do you agree?* *Class: Yes* *Teacher: Then my question is, do the paper have different particles than the book?* *Class: Mumbles* *Teacher: Do a paper have different particles as compared the book* *Class: Mumbles* *Teacher: Simple question, do the paper and the book made up of different particles, that is my question, they are made up of the same particles, the only difference is the arrangement, the only difference is the arrangement, can you see I have folded this one (referring to the paper) can you see it anymore, the paper you can't see it (as she folded the paper in her fist) the book Zack try something, try something (the student trying to fold the book) that means he needs more energy than John (paper) do you get the difference between the density, thank you guys you may set down,*	**<u>Comment</u>**: In this discussion, the teacher is exposing learners to comparison of different materials to get learners to understand the concept of density of different materials. **Teacher Amanda's Role:** The teacher asked learners to explain which one was denser between 1 paper of the book and the entire book (RP) **Learners' Response:** Learners responded that the book was denser than the book (LP). Teacher Amanda's Role: The teacher then explained to learners that while the paper and the book were made up of the same material but the particle arrangement in these two was different which made the other one denser than the other (CS) In this teaching segment, the teacher is using demonstration to teach learners about the concept of density. There were two components of TSPCK at play in this episode and were RP-LP-CS. The TSPCK Map for this episode is: 
17:48-21:37min: *Teacher: the other day I even made eeeeh, an example where is my duster, okay what is this the other day I even made eeeeh, an example where is my duster, okay what is this*	**Comment:** In this teaching segment, the teacher is consolidating the session on density and particle arrangement. **Teacher Amanda's Role:** The teacher is using demonstration as means to foster understanding of what is meant by Density (RP).

Class: Chalk *Teacher: a piece of ……….* *Class: chalk* *Teacher: Sanukundigqibezelela please what is this?* *Class: This is….* *Teacher: (intercepting) this is ayiphethwanga nguwe* *Class: That is a piece of chalk* *Teacher: What is this?* *Class: Mumbles* *Teacher: Come again* *Class: That is a duster* *Teacher: Which one is denser that the other one? X3* *Class: Mumbles:* *Teacher: come again* *Class: Mumbles* *Teacher: A duster is denser than a piece of chalk eeeeh John may you come and Jack come upfront* *Students: coming up to the front as called by teacher* *Teacher: Have this duster Hold it up and face the class (to the other student) hold your piece of chalk up, can you please at the same time break your duster into two pieces, break your piece of chalk into two pieces* *Students: the one with chalk breaks the chalk successfully and the one with duster couldn't* *Teacher: That means you say a duster is denser than the piece of chalk because we see that when you want to fold it or when you want to change it to another shape it takes time that means they need more energy, thank you are there any questions in another words if you were not talking about science density if you were talking about English that means you were going to say it's harder something which is hard, density has something its eeeeh referring to something which is hard but because we are talking about science we talk about the density, are there any questions, thank you very much seat down….eeeh*	In her explanations, the teacher is using different materials with different masses [given that the volume is kept same in the materials under comparison] to focus learners to the concept of Density. The teacher further mentions that in these materials, the particle arrangement is different and therefore the energy needed to break them is higher as the density increases **(CS)** The teacher is using different demonstrations to emphasis this concept of energy and particle arrangement in materials that are denser and therefore using knowledge of representations to come up with a teaching strategy to demonstrate the concept of density (CT/RP). From the previous two episodes, the teacher is asking learners and as they respond the teacher confronts the misconception or confirm the correct understanding (LP) In this teaching segment, there are three components of TSPCK used interactively to explain density. It then follows that this episode is categorized as that which shows proficient TSPCK Episode. The resulting TSPCK Map from the sequence of this episode 

*Pseudonyms have been used in the table above to protect true characters of the teacher and students

The in-depth analysis conducted in the Table 7.5 were put into pictorial representation to visualize the sequence various types of TSPCK episodes emerging at various time along the course of the lesson. In Figure 7.3 is a teaching profile for lesson 2 of teacher Amanda post the intervention.



3:22-3:58 **3:53-5:58**

Total Simple TSPCK Episodes = 0 Total Proficient TSPCK Episodes = 5 Total Sophisticated TSPCK Episodes = 2

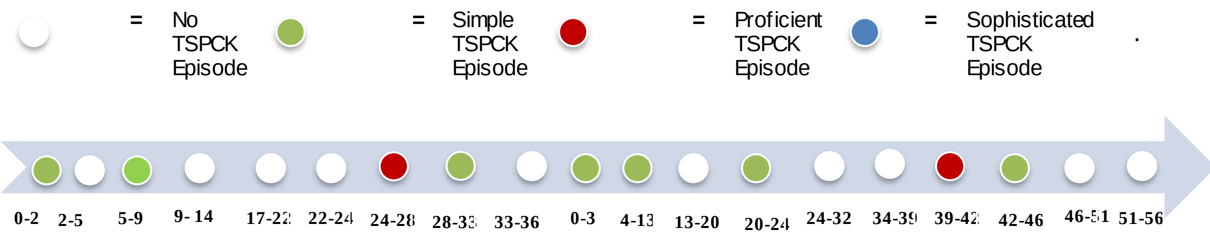
Figure 7. 1: Amanda's teaching profile for post-intervention lesson 2

While in this chapter only analysis of one teacher is presented, analysis for teacher Sophie and Noreen's lessons were analysed the same way. The detailed analysis for the rest of the OFTs is given as Appendix 15, 16, 17 and 18. The choice of teacher Amanda as a sample to show the analysis was informed by an observation that her lessons prior the intervention reflected the real issues such as poor quality of teaching science in the rural schools of Eastern Cape. Her lessons post the intervention were also revealing the potential effect of PCK at the topic level in improving science teachers' knowledge for teaching the particulate nature of matter.

Lesson Focus: Phases of Matter

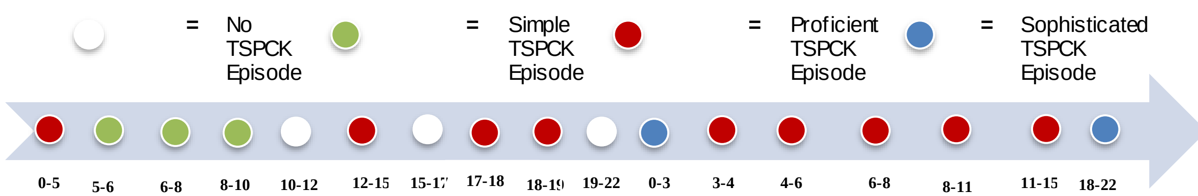
Teacher Amanda 'teaching TSPCK profiles'

Amanda's Lesson 1 & 2: Pre- Intervention

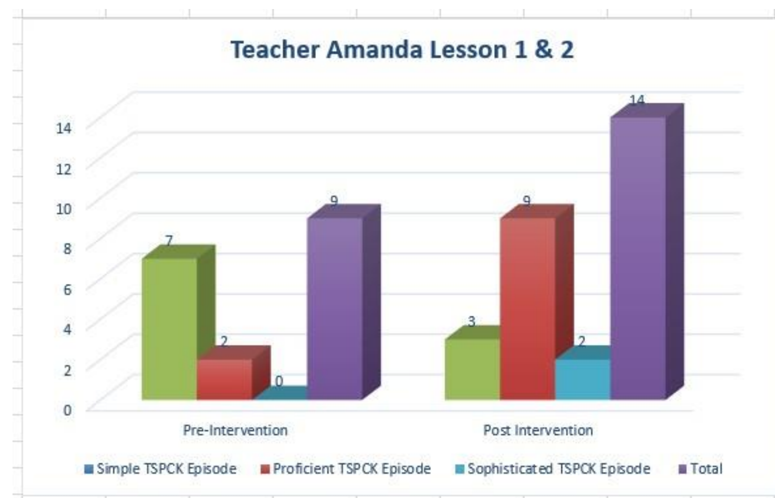


Total no TSPCK Episodes = 10; Total **Simple** TSPCK Episodes = **7;** Total **Proficient** TSPCK Episodes = **2;** Total **Sophisticated** TSPCK Episodes = **0; Total** = **9**

Amanda's Lesson 1 & 2: Post Intervention

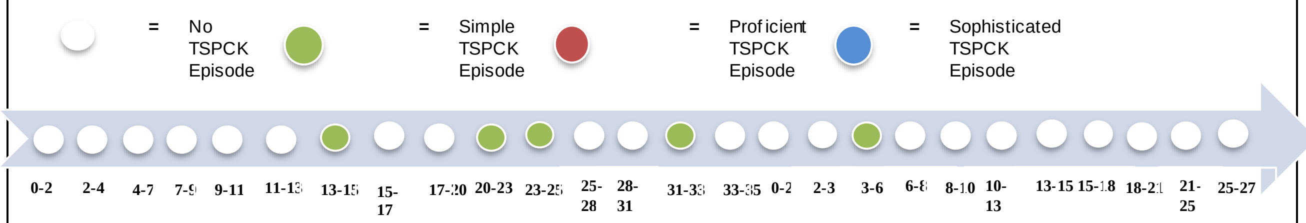


Total No TSPCK episode = 3; Total **Simple** TSPCK Episodes = **3; Total Proficient** TSPCK Episodes = **9;** Total **Sophisticated** TSPCK Episodes = **2; Total = 14**

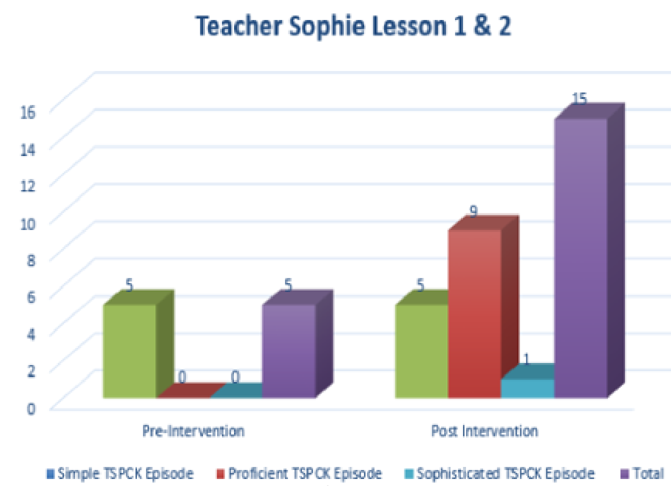


Teacher Sophie ‘teaching TSPCK profiles’

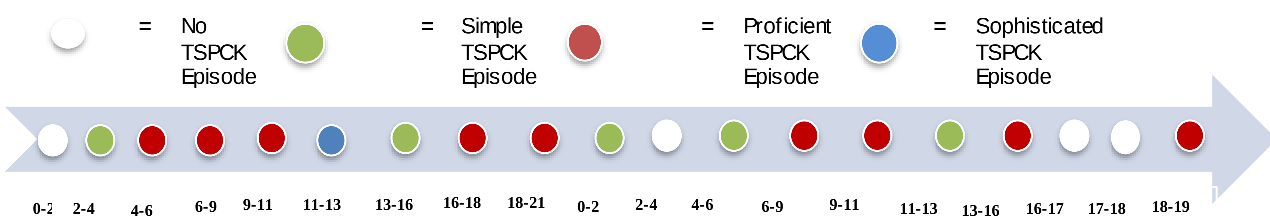
Sophie’s Lesson 1 & 2: Pre-Intervention



Total no TSPCK Episodes = 19 Total **Simple** TSPCK Episodes = **5** Total **Proficient** TSPCK Episodes = 0
Total **Sophisticated** TSPCK Episodes = **0**
Total = 7



Sophie’s Lesson 1 & 2: Post-Intervention



Total no TSPCK Episode = 4 Total **Simple** TSPCK Episodes = **5** Total **Proficient** TSPCK Episodes = 9 Total **Sophisticated** TSPCK Episodes = **1** **Total = 15**

Teacher Noreen’s ‘teaching TSPCK profiles’

Figure 7.4: Teaching profiles and lesson overviews for OFTS pre/post-intervention lesson

The study looked at the impact of a signature intervention with an explicit focus on PCK on the quality of ePCK of the OFTs at a topic-specific level. Aydeniz and Kirbulut (2011) argue that the development of planning to teach knowledge does not automatically translate into actual classroom teaching. This meant that the construct of PCK entails more than just knowledge to plan, but also knowledge to teach in a real classroom teaching context. The recent revision of the consensus model for PCK positions eTSPCK as one of the key grain sizes of PCK and as much important as all other grain sizes of PCK. Thus, at this point of the research study, the main aim was to look at the impact of an explicit TSPCK intervention on the quality of ePCK. The main research question was "*what impact does the face-to-face intervention have on the quality of enacted TSPCK in the topic of intervention.*

Data analysis have revealed that prior to the intervention the OFTs' TSPCK episodes were mostly consisting of simple episodes with a total n=23 out of a total of 25 TSPCK episodes overall for all three OFTs. The quality of OFTs' TSPCK episodes prior the intervention meant the explanations provided to explain concepts during classroom teaching were only limited to use of only two TSPCK components interactively and these kinds of explanations were dominant in their episodes. The kinds of explanations provided by the OFTs was poor and only limited to general, circular knowledge about matter without any links to the particulate nature of matter as required by the curriculum at Junior Secondary level. As a result, the most dominating trend in the pre-intervention lessons were explanations categorized as those containing no TSPCK episodes. These zero TSPCK episodes were reflections of lessons of dominated by common knowledge to explain concepts.

In the post-intervention lessons, however, new qualities emerged quite strongly. The TSPCK episodes of higher-order quality with at least three components used interactively to formulate richer explanations were dominating. This meant more proficient TSPCK episodes dominated the OFTs' explanations post the intervention. For example, the increased number of proficient TSPCK episodes is evidenced by a shift from n= 2 in the pre-intervention lessons for all three OFTs to n= 29 proficient TSPCK episodes in the post-intervention lessons.

There was an observable shift in the quantity and quality of the TSPCK episodes before and after the intervention. The dominant episodes post the intervention was a combination of simple and proficient TSPCK episode with some sophisticated or exemplary episodes in some cases. This is contrary to a combination of zero TSPCK and a few simple TSPCK episodes prior to the intervention. Furthermore, few exemplary TSPCK episodes were emerged after the intervention as evidenced by n=4 for the entire cohort, compared to zero exemplary TSPCK episodes in pre-intervention lessons. This is evidence that the OFTs' explanations post the intervention were starting to display an interactive use of four components which were working together to explain a single concept. Like PCK, it was observed that the TSPCK episodes were also interacting in more distinguishable interactions that were sophisticated and distinctive (Abell, 2008; Aydin, Demirdogen, Akin, Uzuntiryaki-Kondakci, & Tarkin, 2015; Kind, 2009; Mavhunga, 2015).

The findings from data processing also revealed that the exposure of the OFTs to the intervention did not only improve the quality of TSPCK episodes but also how OFTs used the correct scientific language of the particulate nature of matter for explaining concepts. The pre-intervention lessons of OFTs contained emptier TSPCK episodes as their lessons reflected problems of Natural Science Teachers who were trying to teach the model of the particulate nature of matter. The OFTs centered their lessons around day-to-day scenarios which can be seen at homes such as boiling water, freezing, melting candles, melting ice and others but had little to say why all these observed scenarios were happening using particulate nature of matter.

In the post-intervention lessons, the use of common knowledge was immediately replaced with more focused lessons that attempted to address the topic from the particulate matter of nature perspective. This exposure to the intervention resulted in the OFTs not only gain insights into the meaning of their knowledge on day-to-day scenarios but integrated and focused on the particulate level which is key in teaching this topic.

The introductory sections of the OFTs' lesson after the intervention were setting a new tone which was an indication of the shift in their understanding. The lessons were no longer about what was matter but more about what was matter made up from which assisted the OFTs in quickly focusing lessons into the science of particles of matter rather than matter from a generic perspective. This was not found in the OFT's explanations prior to the intervention. The teacher explanations post the intervention was accompanied by representations of matter from particulate nature of matter perspective and these were used interactively with other TSPCK components to formulate richer explanations. This was an improvement compared to the pre-intervention lessons that were dominated by empty TSPCK episodes with some simple TSPCK episodes. In the post-intervention lessons, the OFTs were reflecting a gain in knowledge, as they were able to explain concepts such as intermolecular forces acting between the particles as the cause of spaces in three phases of matter. There was also evidence of a shift in understanding as their pre-intervention lessons only referred to small spaces (solid) or big spaces (gases) without explaining in the scientific language used in teaching the topic but in their post-intervention lessons concepts were also explained using the particulate nature of matter model.

These were new revelations about the construct of TSPCK as the above-mentioned shifts show that an explicit TSPCK intervention was able to result in positive shifts of higher TSPCK quality to Natural Sciences Teachers who were teaching without a formal science background. The interventions showed that it was possible to improve the eTSPCK of the OFTs by replacing their common knowledge perspective of explanations with the correct scientific language used to describe concepts.

Finally, providing NS teachers with correct scientific language also decreased the difficulties of teaching a topic using common explanations as observed in the pre-intervention lessons. The OFTs struggled with the language and resorted to using vernacular language. However, in replacing the vernacular when the OFTs had the correct scientific language to explain concepts, the use of the vernacular language decreased significantly post the intervention. The OFTs were able to use the correct terms to describe concepts post the intervention leaving little room for vernacular language. For example, it is difficult to find a vernacular word for intermolecular forces and when the OFTs had the knowledge of these words and their importance in teaching the topic, their lessons focused on the topic rather than talking about matter generally.

Thus, it can be concluded that after exposure to an explicit TSPCK intervention, the OFTs experienced positive shifts in their eTSPCK quality. The quality of TSPCK episodes, scientific knowledge and correct language for teaching the topic were in various areas, that improved in the OFTs' lessons post the intervention.

7.5 Conclusion and shifts observed across the pre- & post- teaching TSPCK profiles

New patterns and qualities emerged from the data analysis for the impact of explicit TSPCK-based intervention on the quality of the OFTs' enacted TSPCK in the topic of the particulate nature of matter. During the intervention, one of the special features of the intervention included the interactive use of CK concepts as prescribed by the curriculum at the GET phase together with the TSPCK components through real-classroom scenarios to drive discussions during the intervention. This approach is special because it demonstrates how the TSPCK construct restructures during the enactment and therefore resembles the actual operations of a teacher. This approach aligns and fits one of the definitions of the effective professional development programmes that argue that target and focus should be on CK development, practice-orientation and participation among many other features (Supovitz & Turner, 2000). In this study, the OFTs did not only end with the face-to-face intervention but were allowed to practice and participate through classroom teaching.

The first key aspect that emerged strongly from data analysis was an increase in the number of proficient TSPCK episodes in the post intervention lessons of the OFTs. There was an observable shift in the quantity and quality of the TSPCK episodes before and after the intervention. The dominant episodes post the intervention was a combination of simple and proficient TSPCK episode with a few sophisticated episodes in some cases. This is contrary to a combination of zero TSPCK and a few simple TSPCK episodes prior to the intervention. For example, the increased number of proficient TSPCK episodes is evidenced by a shift from n= 2 in the pre-intervention lessons for all three OFTs to n= 27 proficient TSPCK episodes in the post-intervention lessons. This meant that, in the pre-intervention lessons, the explanations of the OFTs displayed mostly the simple TSPCK episodes and this is shown by a total n=23 in pre-intervention lessons for all three teachers.

According to the rubric designed by Miheso (2018), the increase in the number of proficient TSPCK episodes meant that the explanations formulated by the OFTs post the intervention were starting to show interactions of a higher-order quality with at least three components used interactively to formulate richer explanations. These three components were either explicitly distinguishable or addressed implicitly and working together to support an explanation of one concept. This meant that the OFTs were no longer only using two of the TSPCK components interactively as shown by their dominant simple TSPCK episodes prior to the intervention. Furthermore, few exemplary TSPCK episodes were emerging post the intervention as evidenced by n=4 for the entire cohort compared to no exemplary TSPCK episodes in pre-intervention lessons. This is evidence that OFTs' explanations post the intervention were starting to display an interactive use of four components which were working together to explain a single concept. It was observed that the TSPCK episodes were also interacting in more distinguishable interactions that were sophisticated and distinctive than with PCK (Abell, 2008; Aydin, Demirdogen, Akin, Uzuntiryaki-Kondakci, & Tarkin, 2015; Kind, 2009; Mavhunga, 2015).

Secondly, the in-depth analysis further revealed that there was a shift in the correct use of scientific language to describe concepts in the post-intervention lessons compared to the common language used to describe terms in the pre-intervention lessons. In the lessons taught before the intervention, all the OFTs spent most of the lessons teaching the topic from an indirect perspective without getting into detail about the focus of the particle level.

This reflection is evidenced by how teachers introduced the topics post the intervention and the manner the lessons quickly focused on particulate nature of matter using correct scientific representations to teach the topic. For example, in the pre-intervention lessons, teacher Amanda introduced the topic by asking them what is matter and the explanations that scaffolded the lesson was that *"matter is anything around us" and* this explanation kept the entire lesson generic.

However, in the post-intervention lesson, the same concept that "matter is anything that occupies space and has mass" was immediately followed by a correct question, "*what is matter made up of*". The "what is matter made up of" was the beginning of the correct development path towards talking about matter from the particulate nature of matter explanations. The teacher explained to learners that matter was made up of tiny particles called atoms and this was a key aspect that was missing before the intervention in all the OFTs' explanations. As a result, in less than 20 minutes into the lesson, teacher Amanda had the following diagram drawn on the blackboard:

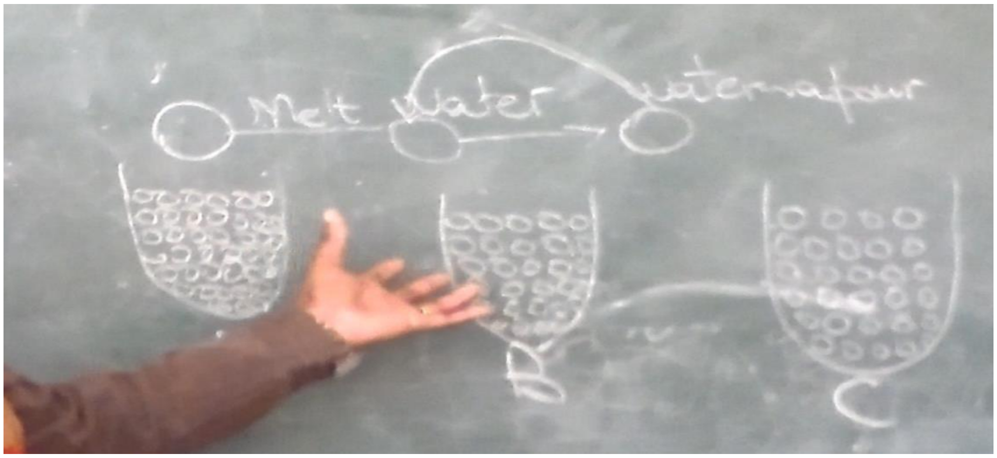


Figure 7.2: Teacher’s representation of particles of the three states of matter

In the diagram in Figure 7.5, while the drawing is not correct however the explanations for each of the phenomenon were correct and this was the key aspect considered for this teaching segment. Teacher Amanda is explaining the concept of phase change through physical processes such as melting, evaporation, freezing and condensation. In the lessons that were taught before the intervention by teacher Amanda, the lessons proceeded without any accompanying representations; however, as indicated by the picture in Figure 7.5, in the post-intervention lessons teacher Amanda was starting to align the teaching of the concept of the model of the particulate nature of matter and phase changes using the particle explanations.

The diagram in Figure 7.5, was also used to explain the differences in the different states of matter using this concept. This trend was observed with all three of the OFTs’ lessons post the intervention. The teachers were also starting to emphasize the concept of *intermolecular forces* acting between the particles in different phases of matter while in the pre-intervention lessons teachers talked about *spaces* without explaining the underpinning theories behind these spaces.

These were significant shifts which revealed that an explicit TSPCK intervention had an impact not only on the TSPCK development of the OFTs but could also correct teaching of the topic from a common perspective of explanations to correct scientific language used to describe concepts. The results reported in this study echo the same sentiments as Abell (2008), Aydin, Demirdogen, Akin, et al., (2015), Kind (2009), and Mavhunga (2015) that explicit focus in correlating the subject and the TSPCK is crucial in developing teachers' PCK in a specific topic.

Finally, the use of common knowledge to explain generic concepts decreased significantly post the intervention, as teachers were gradually using correct terms to describe concepts post the intervention and the vernacular language had little or no place during the lessons. The intervention enabled the OFTs with correct language and terminology to explain phases of matter that immediately replaced the use of vernacular language.

In the post-intervention lessons, the standard definition and generic observations of matter were immediately accompanied by in-depth explanations that addressed the topic from a sub-microscopic particulate nature of matter model perspective. The macro and sub-microscopic explanations were integrated through lesson rather than as stand alone. The lessons taught the phases of matter and how they change using the model of the particulate nature of matter. The teachers also drew more particle diagrams on the chalkboard to help explain to learners how to visualize concepts and these particle diagrams were not found in their pre-intervention lessons. In one of the TSPCK episodes post the intervention all three of the OFTs addressed learner misconception of the particle size during phase change and built up lessons based on this using explanations and representations.

CHAPTER 8

DISCUSSION OF FINDINGS AND CONCLUSION

In the previous three chapters, findings on the impact of the exposure to an explicit TSPCK-based intervention on the quality of the OFTs' CK, planned TSPCK and enacted TSPCK were reported. In this chapter, the findings from the three previous analysis chapters regarding the research questions and research design used and then tying everything back to the proposed theoretical framework for this study are discussed. The entire study within the framework of the *PCK of specific topics is located with a brief background to the situation of out-of-field teaching and the addition new knowledge to the TSPCK literature as a result of the research questions and empirical findings. Finally, the limitations, conclusions and recommendations of this chapter in light of the findings conclude the study.*

8.1 Introduction

The study commenced with a brief re-visit to the history of education in the rural areas of South Africa. In that history re-visit, the realisation that the effects of the apartheid system were still a reality and continued to trouble South Africa to this day. The apartheid system divided the country into urban, peri-urban and rural areas. The rural areas were deprived of among many other things, quality education, particularly mathematics and science education. As a result, rural areas continue to be associated with low levels of literacy, lack of infrastructure or poor infrastructure. The Eastern Cape was identified as one of the provinces that were largely rural and one of the least performing provinces in mathematics and sciences. High teacher attrition rates, specifically Mathematics and Science teachers, were among issues that were identified as causes of out-of-field teaching. The above-mentioned facts premised the context of this study and thus the focus of this study was set on designing a professional development intervention to improve and develop the TSPCK for out-of-field teachers in the rural areas of the Eastern Cape. Hence, the key purpose of the study was to investigate the impact of an explicit

TSPCK-based intervention on the quality of the OFTs' content knowledge (CK), TSPCK and enacted TSPCK (eTSPCK).

After examining the situation of out-of-field teaching, a proposal of a TSPCK-based Professional Development Intervention (PDI) then followed. The proposed PDI was proposed as a platform for on-going learning for out-of-field teachers. The out-of-field teaching is widely characterized as resulting in teachers who are less confident in the manner in which they approach their CK resulting in superficial instructional strategies. The study purposefully extracted key features reported from literature as effective for successful professional development programmes and these features were incorporated in the design of the structure of the intervention. The study also applied the TSPCK construct in the professional development intervention to improve the CK of the OFTs, TSPCK and their eTSPCK in the topic of the intervention.

The Revised Consensus Model (RCM) of PCK, the TSPCK is one of the stated grain sizes of the PCK across the three realms from which development can be experienced Mavhunga (2019). Thus, the Mavhunga and Rollnick (2013) model which define the knowledge components from which transformation of content knowledge emerges at Topic-Specific level was best suitable for framing this study. In addition, the incorporation of the RCM as the most appropriate PCK was informed by the fact that the model reflects the most recent conceptualisations of PCK across the globe. These included PCK conceptualizations that have been widely tested in a South African context such as the TSPCK for teaching science topics. The community of science education research positions PCK and by inference, TSPCK, as professional knowledge specialized for the pedagogical transformation of content knowledge into little bits that can be easily understood by students. The revised consensus model of PCK re-affirmed PCK as special knowledge for teaching science.

A wide range of studies has been reported to have a positive impact in the developing of TSPCK in pre-service teachers and their counterpart content knowledge thereof. As a result, at the beginning of this study, of particular interest was the impact of the TSPCK-based intervention on the quality of the OFTs' content knowledge, TSPCK *and* eTSPCK. In the section for reflections on the research process, reflections on the outcomes of this study concerning the design of a professional development intervention (PDI) were looked at. Two major principles were applied in the design of the PDI.

The first principle was the methodological elements (the "how to run it") of an effective CPD and the key to this principle was continuity and sustainability. The second principle that the designed PDI rested upon was the construct of collective PCK (cTSPCK) for teaching specific science topics. Both these principles were discussed in detail in chapters 2 and chapter 4. Next, there was a reflection on the findings of the impact of the designed intervention on the quality of the OFTs TSPCK, CK and eTSPCK in light of the corresponding research questions of each of these developmental realms.

8.2 Answering research questions

The main question that guided this study was: What is the impact of an intervention with an explicit focus on TSPCK on the quality of teacher knowledge and classroom practice of rural-based Natural Science Teachers, teaching out of the field of expertise? The main research question was then divided into three sub-questions. These sub-questions are discussed in detail in the section following.

RESEARCH QUESTION 1: The first sub-research question was phrased as follows; 'What is the impact of the intervention on the OFTs' CK in the topic of the particulate nature of matter?'

The intention of this research question was to investigate the impact of the intervention of the OFTs' understanding of the CK of the particulate nature of matter as a result of exposure to an explicit TSPCK intervention. Data was collected through the TSPCK tools that consisted of CK questions in the particulate nature of matter. These tools were administered in a set of pre- and post-tests. The data analysis showed that the OFTs improved in the understanding of the concepts in the particulate nature of matter post the PDI with a positive statistically significant gain of 0.001 which is far less than 0.05 significance level. This meant the OFTs experienced a substantial gain in knowledge of understanding of the CK concepts in particulate nature of matter. These findings were further confirmed by qualitative analysis of the CK tests.

Thus, in answering this research question, findings showed that the OFTs' CK improved significantly after exposure to a TSPCK-based intervention.

RESEARCH QUESTION 2: The second research question sought to investigate the impact of a signature intervention explicitly focusing on the quality of the OFTs' TSPCK. The research question was phrased as follows: 'What impact does the intervention have on the quality of OFTs' TSPCK in the topic of the particulate nature of matter?'

TSPCK tests were administered before and after the intervention to measure the shifts (if any) on the quality of TSPCK as a result of direct exposure to a signature intervention focusing on TSPCK. Data analysis indicated that there were positive shifts experienced by the OFTs towards a higher-order of the quality of TSPCK categories according to the rubric. The quality of the OFTs' TSPCK in the particulate nature of matter increased from a lower overall group score which reflected a basic level of the TSPCK (denoted by a score of '2') to a higher overall average score which reflected developing the quality of TSPCK (denoted by a score of level '3') immediately after the intervention.

The shift to the level of 'Developing TSPCK' category is an indication that after exposure to the intervention, the OFTs reflected on their TSPCK tests evidence of teacher responses that drew from at least three of the TSPCK components interactively in formulating explanations. This is contrary to their pre-tests that reflected the use of only one or two TSPCK components.

The TSPCK component interactions that resulted in the newly established score post the intervention are what Mavhunga (2015) regards as indicators of quality TSPCK in a specific topic in the particulate nature of matter. Thus, in answering the research question posed, it could be said that the OFTs were able to improve their quality of TSPCK particulate nature of matter after exposure to an explicit intervention.

RESEARCH QUESTION 3:

The third question of the intervention asked: 'What impact does the intervention have on the quality of OFTs' eTSPCK in the topic of the particulate nature of matter?'

In this research question, the focus was on the impact of the intervention on the quality of the TSPCK observed during real classroom practice. At this point, the main source of data was video-recorded lessons of OFTs in real classroom teaching of particulate nature of matter before and after the intervention. The video-recorded lessons were divided into teaching segments that were then analysed for TSPCK episodes using the rubric TSPCK in action.

The analysis has revealed that the quality of enacted TSPCK of OFTs improved post the intervention. The shift in the quality of the enacted TSPCK was observed in the teaching segments that were dominated by a mix of zero TSPCK episodes and simple TSPCK episodes to teaching segments that were dominated by proficient TSPCK episodes with few exemplary episodes. The shift in the quality of the TSPCK episodes between pre and post-intervention lessons is evidence that after exposure to TSPCK-based PDI, the OFTs' post-intervention lessons reflected teacher responses that used at least three of the TSPCK components interactively in formulating explanations. Sometimes, the OFTs drew from four of the TSPCK components interactively to formulate richer explanations even though these kinds of episodes were very few. It is this kind of higher-order interactions of the TSPCK components that are categorized as indicators of quality enacted TSPCK in a specific topic.

Thus, in answering this research question, it can be asserted that the OFTs were able to improve the quality of enacted TSPCK in the particulate nature of matter after exposure to an explicit TSPCK-based PDI.

8.3 New knowledge contributions the study

The study has made contributions in the field of PCK specifically showing with evidence that it is possible to develop and improve the CK, pPCK and ePCK at the Topic-Specific level for pre-service science teachers who are teaching out of their field of knowledge in the rural areas. This study adds the context of out-of-field science teachers and provides evidence of the effectiveness of TSPCK to fast-track development of the knowledge TSPCK of Natural Science Teachers. The study demonstrated that a professional development intervention which explicitly exposed the OFTs to the knowledge construct of the collective TSPCK does improve the TSPCK of the OFTs.

This study makes an important contribution as it is the only study that takes the construct of TSPCK to address the inadequacies of the out-of-field Natural Science Teachers at Junior Secondary level, as opposed to the majority of the PCK studies in South Africa that are normally done with the FET teachers. In all, the findings from this study revealed that an explicit cTSPCK intervention has a positive impact not only on the OFTs' CK, pPCK and ePCK in the particulate nature of matter but also enriched the correct scientific language used to describe concepts. This resulted in a shift from lessons taught from a common knowledge perspective to a more constructive lessons that are addressed the topic from the particulate nature of matter model.

Furthermore, PCK-based intervention was observed to supplement the use of only vernacular language into integrated lessons that also used correct scientific language associated with the particulate nature of matter. Teachers in rural areas are known for teaching in their respective vernacular languages without referring to concepts by their corresponding scientific terms. Therefore, these were significant and new revelations by this study especially considering the challenges of teaching in rural areas where all subject areas are mostly taught in vernacular language including science. PDI equipped OFTs not only with the knowledge for teaching science but also enriched their language of instruction to a more code-switching approach than a mere group singing of the common knowledge scenarios associated with science.

8.4 Critical reflections on the research design

8.4.1 Reflections on methodology

The research methodology used for this study was the Mixed Methods (MM) approach. The key attraction to this choice of research methodology was that it offered an exploration of data from a quantitative and a qualitative perspective. To get deeper insights on data collected through the TSPCK and CK tests the Rasch model was used to analyse data quantitatively. The Rasch measurements allow a hierarchal estimate of a teacher's ability in response to the order of item difficulty in the TSPCK tests (Boone et al., 2014). Such measurements gave this study deeper analysis to look into the TSPCK components that the OFTs found the most difficult and the easiest as revealed by order of difficulty of the TSPCK components.

This study took a case study research approach to explore interactions of the construct in deeper detail regardless of the sample size. Therefore, this study was a rich case analysis for understanding the impact of the TSPCK in the particulate nature of matter for Natural Science Teachers who were teaching out-of-field in a rural context. However, due to the use of case study research approach, the findings of this study cannot be generalized.

In addition, the data collection methods that were envisaged included interviews before and after enactment of the observed lessons to get deeper insights into the pedagogical reasoning and thinking of teachers. However, due to the background of the teachers in this study, upon analysis of these data collection methods, it was realized that these interviews were short and off the purpose of the study. An example of a transcribed interview is given in chapter 3.

8.4.2 Reflections on the nature of PCK at the Topic-Specific level

The PCK construct that was used as a theoretical and analytical framework of this study was at Topic-Specific level. The model of Mavhunga and Rollnick, (2013) specifically conceptualized the study on the model of the TSPCK. The focus of this framework was the transformation of content knowledge into a teachable form through five content-specific knowledge components for learners to understand. This makes content knowledge a pre-requisite in driving any discussions around transformation into teachable forms. This was a challenge with out-of-field teachers due to their poor background of content knowledge. As a result, while all five components of the TSPCK were discussed for the effectiveness of the intervention on the OFTs' practice, the study had to focus more on knowledge components which are known to expose teachers to the nature of TSPCK. These were learner prior knowledge, curricular saliency and representations. However, on the contrary, teachers in this study found items on *"what is difficult to teach"* easier than those in curricular saliency both pre and post the intervention.

In addition, the knowledge component of teaching strategies was found to be one of the most difficult items of the TSPCK tools followed by curricular saliency. The out-of-field teachers were exposed to an intervention that focused explicitly on the TSPCK in the topic of the particulate nature of matter. It is a common understanding within PCK scholarly work that the acquired knowledge of PCK in one topic does not transfer to another topic (Aydin et al., 2014) and this is the nature of TSPCK at this level. This becomes one of the key limitations of PCK at Topic-Specific level. However, while the PCK in any specific topic is not transferrable to another topic it is also argued that the pedagogical transformation competence (PTC) developed through learning one topic can be transferred to other topics for the same purpose of developing PCK in that other topic (Mavhunga, 2016; Miheso, 2018). Key to teaching teachers TSPCK is learning the ability to transform content knowledge through the five components of PCK as well as the interactive use of these components in to formulate explanations in a specific topic. It is this learnt ability that Mavhunga (2016) defines as constituting the competence needed to transform CK into a teachable format and which referred to as PTC. The success of PTC is learnt through the topic of intervention and is evidenced by shifts in the quality of TSPCK as portrayed by tools such as CoRes and TSPCK tools. There is evidence of success in the transferability of PTC once learnt in the topic of intervention to another, which creates a possibility of teachers being able to develop their PCK across topics in a specific discipline through this learnt competence. Thus, the PTC learnt by the teachers in this topic could be used by the OFTs to plan to teach another topic. The PTC offers teachers with a framework to use when planning and teaching a different chemistry topic.

8.4.3 Reflections on the intervention

At the conceptualisation stage of this intervention, the aim was to ensure that the intervention was not only a once-off injection type of approach. However, due to time limitations that included stipulated time to finish the PhD study after three years and geographical locations between researcher and the teachers in the Eastern Cape, meeting more frequently became impossible. Therefore, the study ended up taking one week of face-to-face contact of unpacking and rebuilding the transformation components of PCK at the Topic-Specific level. However, the one week was enough for unpacking and r-ebuilding the transformation components.

The use of CoRes allowed the OFTs an opportunity to develop their TSPCK collaboratively making it easier to reflect with evidence the developmental pathway of the TSPCK of the OFTs later in the intervention. The advantage of using those CoRes was that the prompting questions that were used, were also based on the construct of PCK in any specific topic. As a result, the OFTs were able to reason the big ideas of the particulate nature of matter through the CoRes. The reflections evidenced by these CoRes added more data for analysis to the TSPCK tests and episodes compared to those with the OFTs' reasoning prior to the intervention. The CoRe-based exercises became the main indicator of evidence of development and improvement in the quality of the OFTs TSPCK during the intervention.

However, due to the complexity of proximity between schools in rural areas, it was impossible to visit schools for all fifteen OFTs to further look into their acquired knowledge in TSPCK in the classroom. Thus, it was envisaged that the integration of technology could be considered as a route for sustained PDI to counteract the limitations explained above, and therefore a WhatsApp platform was created to further provide support to teachers beyond the face-to-face stage of the intervention. However, upon attempts to analyse these messages, it was realized that the messages were not substantive in supporting what this platform intended to do. The data from this platform was not used. While the integration of technology is a key concept in the fourth industrial revolution era, a better design of how best technology can be integrated into the PDIs such as one designed for this study would need to be incorporated from conceptualisations with clear instructions to drive effective discussions. These are the platforms that further research could explore beyond WhatsApp to include other platforms such as blogs, discussion boards and collaborative tools.

8.4.4. Limitations of the study

Several limitations have emerged from this study due to: as the sample size was of only fifteen out-of-field teachers who participated in the face-to-face intervention. These participants were Junior Secondary Teachers in a particular district and who have a professional development network that specifically focuses on improving their content knowledge. The targeted sample was twenty teachers, but some excused themselves as they were coming from as far as Mt Frere which is more than 150 km away. However small the sample may be, this did not affect the significant differences between pre and post the TSPCK tests administered in this study. Wilcoxon paired signed-rank test for non/parametric data. (Whitley & Ball, 2002) was used to calculate the significant paired data. Thus, it is important to highlight that the findings and conclusions of this study may not be generalizable to other professional development interventions.

Another limitation of this study was the proximity of schools in the rural Eastern Cape. During the school visits for structured follow-up support to schools, it was only a sub-set of three teachers from the total fifteen teachers. The selection of these three teachers was due to the geographical proximity of the schools, with approximately over 100 km at a maximum distance between the schools, as well as the physical accessibility to the schools in terms of road infrastructure and ease of ground terrain. The teachers in the district also had other commitments such as teacher union meetings and departmental meetings, which required them to use school hours to travel to these events. This made it difficult to have a clear schedule on school visits; sometimes you would agree to meet at a certain time and only receive an SMS in the morning to postpone the visit. Such constraints had implications on time and budget as the study was conducted away from the Campus. Thus, these constraints limited the analysis of actual classroom teaching to three cases while the enacted TSPCK could have been explored more with additional cases. It was advantageous for these three OFTs because it allowed in-depth analysis of their cases.

8.5. Conclusions and recommendations

Out-of-field teaching is a common practice in rural areas and its implications are bad; however, this problem is understudied as a result of lack of research and out-of-field teaching in science education remains under-discussed. Even when this problem is researched, in most of the cases the problem is generalized to include mathematics and technology rather than focusing specifically on the problem that relates to science education. This study is adding literature to the understudied problem in out-of-field teaching and in science education, demonstrating specifically a possible way of designing effective professional development programme to address the plight of out-of-field teaching in science education. The study has demonstrated with empirical evidence that TSPCK could be used as one valuable construct to guide holistic improvement of the OFTs' TSPCK in all grain sizes of the construct. The construct has been widely reported for bringing positive outcomes in fast-tracking the development of TSPCK for pre-service science teachers. This study has yet validated the value of construct outside the norm which implies that TSPCK could be regarded as a valid construct for teaching science teachers who are in-service teachers. The study has implications in the science education of South Africa specifically in science education as the Eastern Cape Province continues to be troubled by poor learner performances in physical sciences. The study brings a promising possibility of supporting Junior Secondary teachers who are practicing without background knowledge in physical sciences using TSPCK to facilitate the OFT's development of knowledge for teaching science.

It is, therefore recommended that in-service teacher development programmes should not limit such programmes to Content Knowledge but adopt TSPCK as a special and unique construct to address CK deficiencies of practicing teachers. It is also recommended that more research studies are conducted in this area not only in South Africa but across the world to further understand claims made by this study and thus, add more literature into understanding out-of-field teaching.

8.6. Future work

This study revealed that the TSPCK explicit intervention was able to improve the quality of CK, TSPCK and eTSPCK of the OFTs in the particulate nature of matter. As alluded to in the reflections in section 8.4.3, the PTC learnt in the topic of intervention could be transferred as a strategy to develop PCK in another topic. Success on the transferability of PTC learnt for the development of PCK in another topic is reported in many studies (Mavhunga, 2016; Miheso, 2018). Thus, by inference, the PTC learnt by the OFTs in this study when they were exposed to five knowledge components of TSPCK for transforming CK into teachable form need to be evidenced further through research.

Secondly, while the use of technology in this study was only limited to WhatsApp and not explored fully, with the advent of integration of technology into the curriculum, PDIs such as the one designed for this study can no longer be limited to geographical bounds and travelling constraints of the Eastern Cape. For example, there is a growing use and understanding of Learning Management Systems (LMS) such as Blackboard, Sakai and Moodle and such platforms could be utilized to maximize the time spent on the PDIs of the developing teachers' TSPCK rather than travelling and logistics. In essence, this study has shown that there is a dire need to support in-service teachers who are teaching out-of-field, thus, future research should seek ways of maximising time used to discuss the use of TSPCK effectively for the classroom. The use of technology could play a pivotal role in unpacking the components of TSPCK in detail step-by-step and one by one, to unravelling more benefits embedded in the TSPCK construct. The integration of technology into such designs also brings possibilities of a more stable sustainable PDI, with features such as learner analytics that could be used to track the extent of engagement by OFTs and apply immediate interventions where OFTs are having difficulties. It is envisaged that in future such TSPCK based PDIs as the one designed in this study should also take a form of the blended learning approach to decrease competition with teacher union meetings and departmental meetings as teachers will only need their technological gadgets like smart telephones and laptops to be actively involved in continuous development programmes.

8.6. End-piece

Out-of-field teaching is a hidden reality of rural areas across the world and South Africa is not exempted. The problem has implications in the quality of teaching that include superficial teaching strategies with inadequate content knowledge that could in turn have implications on poor learner performances in physical sciences. This study brings evidence with it that explicit exposure to the knowledge components of the TSPCK for the transformation of the CK in a specific topic can improve the said challenges with out-of-field science teachers.

The findings of this study could be used as a basis to advance analysis and research for the under discussed problem with a specific focus on understanding out-of-field teaching concerning science education rather than general discussions of this practice across different subject areas. Integration of technology into TSPCK could bring an added advantage to the above-mentioned limitations with proper instructional design and integration as this could bring endless opportunities to the application of the interactive use of TSPCK components into science classrooms.

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APPENDICES

APPENDIX 1: Ethical Approval Letter

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

30 November 2015

Student number: 0614709F

Protocol Number: 2015ECE018D

Dear Nonkanyiso Vokwana

Application for ethics clearance: Doctor of Philosophy

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:

Evaluation of a content knowledge development model for out of field rural natural science teachers through a teacher professional development program which is Topic Specific-based at GET level.

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

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

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

All the best with your research project.

Yours sincerely,

MMabety

Wits School of Education

011 717-3416

cc Supervisor - Dr Elizabeth Mavhunga

APPENDIX 2: Original TSPCK Instrument

PARTICULATE NATURE OF MATTER TEST

This info is for research purposes only: your responses will be treated confidentially. Pseudonyms will be used if a need to refer arises. This page will be detached and stored separately.

SECTION A: BACKGROUND INFORMATION

NAME AND SURNAME: ______________________________ Gender (tick✓):

Female	Male

HOME province and town: ____

Please fill in details about all post school qualifications. (since you left high school.)

Qualification and length of course	From (year)	To (year)	Main Subjects

Please provide the highest level reached in your science content subjects studied - i.e. science and maths courses (not education or methodology/didactics courses) and the highest level at which you have taught (e.g. grade 11).

Subject	Highest level reached (e.g. 2nd yr univ)	Highest level taught (e.g. G 11)
Chemistry		
Physics		
Physical Science		
(Others)		

Please provide the following information about your teaching.

Number of years	School and province	Subjects taught	Classes taught

Code:………………………………

Code:

1. Give one word or term for each of the following description.

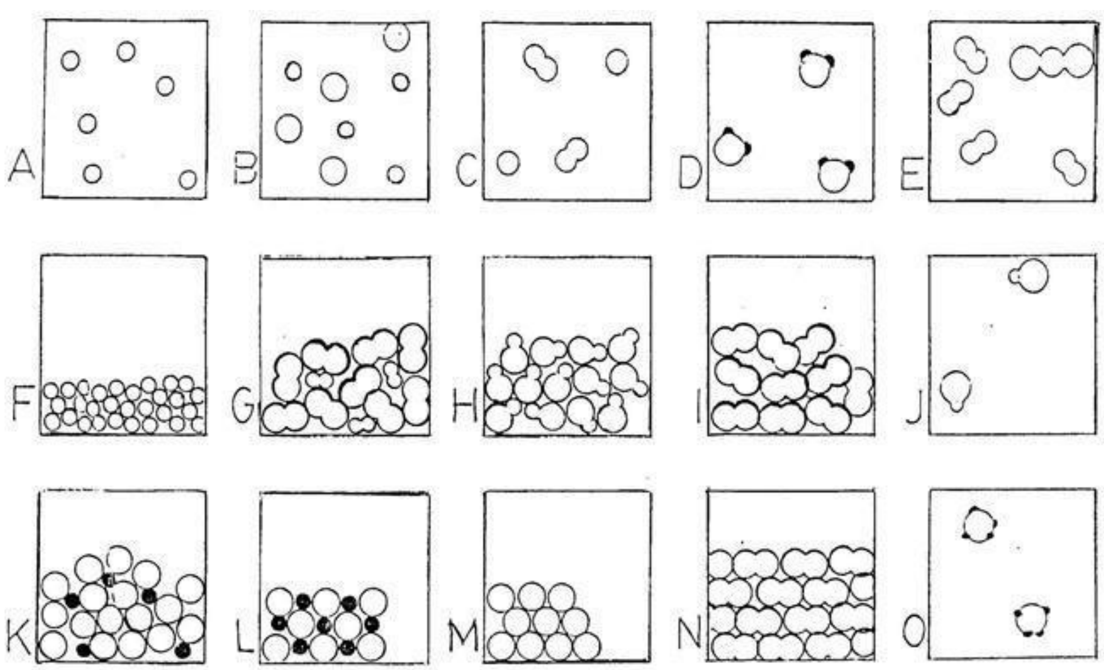
(a) A substance that is made of only one kind of atom.
(b) A substance made of two or more atoms of different elements chemically bonded.
(c) A smallest particle of an element that still retains the chemical properties of that element.
(d) A particle that consists of two or more atoms bonded together.
(e) A substance that consists of different substances that are not chemically bonded to each other and still retain their original properties.

Answers:

(a)______________________; (b)______________________; (c)______________________

(d)______________________; (e)______________________

2. In the diagrams below say:



(a) Which diagram(s) consist(s) of only one element?
(b) Which diagram(s) consist(s) of only one compound?
(c) Which diagram(s) represent(s) a mixture?
(d) Which diagram(s) represent(s) a pure solid?
(e) Which diagram(s) represent(s) a pure liquid?
(f) Which diagram(s) represent(s) a gas?
(g) Which diagram(s) represent a pure substance?
(h) Which diagram(s) represent molecules only?

Answers

(a)____________________; (b)____________________; (c) ____________________;

(d)______________________; (e)_____________________; (f)_________________________

(g)______________________; (h)____________________

3. Draw microscopic representations of oxygen as it heated from a solid to a liquid to a gaseous state in the boxes below. Use  to represent a single molecule. Draw 9 molecules in each box.

Solid

Liquid

Gas

4. Question 1 to 4: are the following statement true (T) or false (F)?
Circle the correct answer and indicate the degree of confidence i.e. 100% sure, not sure or guessing.

(1) All molecules of a given pure substance are identical. **T/F**

100% sure	*Sure*	*guess*

(2) Between molecules of a substance there is "empty space". **T/F**

100% sure	*Sure*	*guess*

(3) A molecule of a substance in the solid phase has larger mass than a molecule of the same substance in the gaseous phase. **T/F**

100% sure	*Sure*	*guess*

(4) The forces of attraction between molecules of naphthalene in the liquid phase are greater than in the solid phase. **T/F**

100% sure	*sure*	*guess*

5.

(a) Name the sub-atomic particles found in the nucleus of an atom?

____

(b) What type of charge is found on each of the above mentioned sub-atomic particles?

____

(c) Fill in the blanks on the following table.

Element	Notation	Atomic number	Mass number	Number of protons	Number of electrons	Number of neutrons	Number of nucleons
				20	18		
Fluoride ion	$^{19}_{9}F^{-}$						
	$^{23}_{13}Al^{3+}$						
				17	18		

(d) Which of the following unidentified elements are isotopes of one another?

${}^{12}_{6}X$, ${}^{12}_{7}Y$, ${}^{24}_{12}A$, ${}^{14}_{6}Xy$, ${}^{13}_{6}Mp$ (note: X, Y, A, Xy and Mp represent the symbols of unspecified elements).

____

How did you work out the answer above?

____

What is the name of an isotopic element represented in (d)?

____

(e) Chlorine consists of two isotopes ^{37}Cl and ^{35}Cl. The average atomic mass of naturally occurring chlorine is 35,5amu. Which of the following percentages of the two isotopes is most likely in naturally occurring chlorine? **Justify your choice**

	% ^{35}Cl	% ^{37}Cl
A	50	50
B	67	33
C	33	67
D	99	1

____

____

____

____

____

PARTICULATE NATURE OF MATTER PCK TEST

This info is for research purposes only: your responses will be treated confidentially. Pseudonyms will be used if a need to refer arises. This page will be detached and stored separately.

SECTION A: BACKGROUND INFORMATION

NAME AND SURNAME: ______________________________ Gender (tick✓):

Female	Male

HOME province and town: ____

Please fill in details about all post school qualifications. (since you left school.)

Qualification and length of course (e.g. STD - 3yrs)	From (year)	To (year)	Main Subjects

Please provide the highest level reached in your science content subjects studied - i.e. science and maths courses (not education or methodology/didactics courses) and the highest level at which you have taught (e.g. grade 11).

Subject	Highest level reached (e.g. 2nd yr univ)	Highest level taught (e.g. G 11)
Chemistry		
Physics		
Physical Science		
(Others)		

Please provide the following information about your teaching.

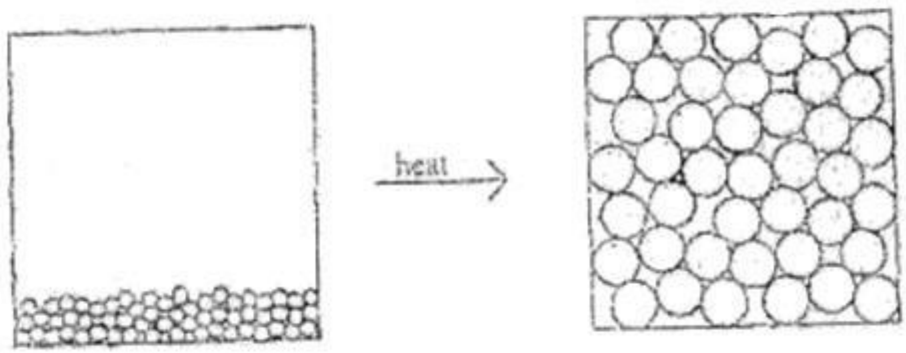
Number of years	School and province	Subjects taught	Classes taught

Code: ……………………………….

Code:

CATEGORY A: LEARNERS' PRIOR KNOWLEDGE

1. Learners in a grade 10 class were asked to represent the change that takes place when a substance is heated. The response Teboho has written on the board is shown below.



How would you comment on Teboho's response as part of an explanation to the rest of the class?

Response A: Teboho's response is incorrect. All substances have small particles called atoms that may combine chemically with each other to form molecules. When substances are heated their molecules do not expand in size. The size of the molecules stays the same.

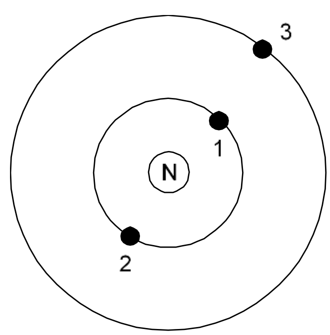
Response B: Teboho's response is incorrect. When a substance is heated, molecules gain kinetic energy. The molecules will start vibrating and the bonds between them weaken to allow re-arrangement and in some cases allowing the molecules to move away from each other. The molecules themselves do not change in size when heated. It is the re-arrangement of molecules that changes.

Response C: Teboho's response is incorrect. When a substance is heated, a phase change occurs. The molecules of a substance become more free from each other as the bonds are weakend in some cases completely broken. Substances that were originally solids may become liquids and liquids may become gases

Response D: None of the above

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

My choice is Response …..



A simple representation of an atom

2. When learners were asked to describe what is happening in the given atomic model above, Lerato gave the following written response:
   An electron further away from the nucleus (electron 3) would experience less attraction to the nucleus.

What comment(s) would you write on her paper?

Response A: True, electron 3, located further away from the nucleus, will not be attracted in the same way as the electron closer to the nucleus.

Response B: True, the electrons on the energy levels further away from the nucleus experience a smaller force of attraction than those which is in nearer energy levels. However, all electrons are attracted by the same type of force from the nucleus.

Response C: True, electron 3 will experience less attraction towards the nucleus because of the greater distance between the electron and the nucleus.

Response D: None of the above

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

My choice is Response …..

CATEGORY B: CURRICULUM AWARENESS

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

3.1 What do you consider to be the four main ideas (main concepts) to be taught about particle nature of matter at Grade 10? Choose from the list provided.

Particles are in constant motion	Substance have subatomic particles
Molecules have forces between each other	Compounds are made up of atoms
Elements are made up of atoms	Atom has a specific structure
Matter is made up of small bits that are called particles	There are different type of small bits of substance
Atoms are smallest particle	Matter is found in different phases
Molecules are made from atoms	Other
There are different atomic theories	

1.
2.
3.
4.

3.2 In what sequence would you teach the main ideas you have identified above?

3.3 Make a map or a diagram of these four ideas showing how they link to subordinate ideas

3.4 What other topics in chemistry do you think require the understanding of particle nature for teaching them?

3.5 Why is it important for learners to learn about particle nature of matter? Identify reasons related to:

i. Conceptual Progression
ii. Application
iii. Motivation or Interest

CATEGORY C: WHAT MAKES THE TOPIC DIFFICULT TO UNDERSTAND?

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

Concept	✓	What exactly makes it difficult?
There is an empty space between particles of matter		
Particles are in constant motion		
There are different types of small bits of substances.		
Calculating the relative atomic mass of an isotope		

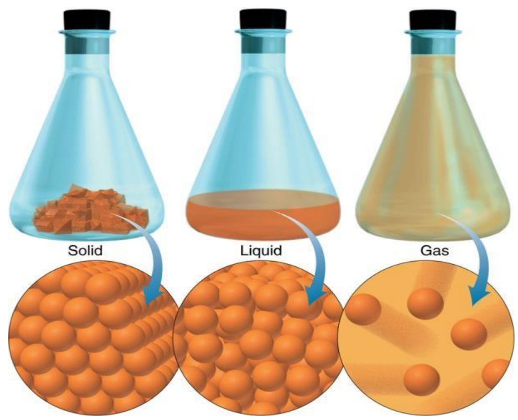
Concept	✓	What exactly makes it difficult?
Finding number of electrons in an ion for example $^{24}_{12}Mg^{2+}$		

5. CATEGORY D: REPRESENTATIONS/ MODELS

Phases of Matter

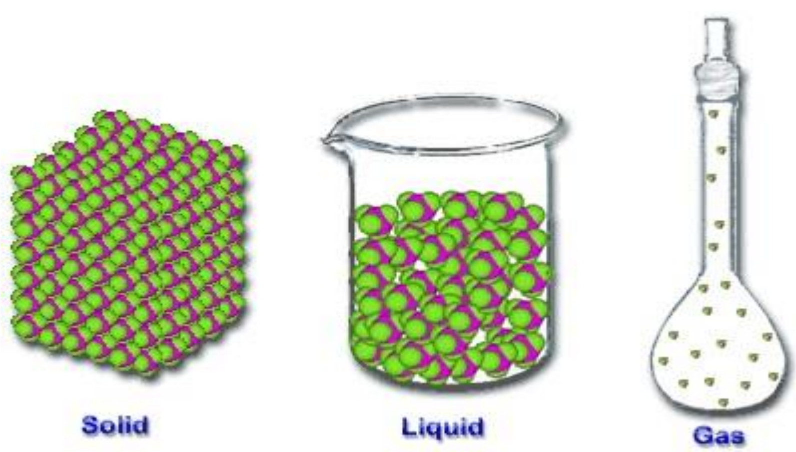
Below are three different representations that can be used for teaching phases of matter. Decide which one(s) you like and complete the table below

Representation 1



Representation 2

Representation 3



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

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

5.2 Which representation do you like most?

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

CATEGORY E: TEACHING STRATEGIES

Average relative atomic mass

Shown below is a learners' response to a written test meant to assess learners' prior knowledge on average relative atomic masses.

Question

Calculate the average relative atomic mass of a sample of oxygen gas that contains the following isotopes of oxygen atoms:

Element	Isotopes	Isotopic mass	Percentage abundance
Oxygen	^{16}O	16	99,790
	^{17}O	17	0,037
	^{18}O	18	0,173

A learner's response:

O-16: 16
O-17: 17
O-18: 18

16+17+18=51
51 ÷ 3= 17amu

Following the learner's response, how will you teach a lesson on calculating the average relative atomic mass?

Estimate how long it took you in total to complete this assignment: _____________

APPENDIX 3: Adapted TSPCK instruments in particulate nature of matter

University of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg sa t+27 11 7173 265 f+275167237

PCK Research group

Contact Person: Prof. Marissa Rollnick

E-mail: Marissa.Rollnick@wits.ac.za

PARTICULATE NATURE OF MATTER DIAGNOSTIC TOOL

PARTICULATE NATURE OF MATTER TEST

This info is for research purposes only: your responses will be treated confidentially. Pseudonyms will be used if a need to refer arises. This page will be detached and stored separately.

SECTION A: BACKGROUND INFORMATION

NAME AND SURNAME: ______________________________ Gender (tick✓):

Female	Male

HOME province and town: ____

Please fill in details about all post school qualifications. (since you left high school.)

Qualification and length of course	From (year)	To (year)	Main Subjects

Please provide the highest level reached in your science content subjects studied - i.e. science and maths courses (not education or methodology/didactics courses) and the highest level at which you have taught (e.g. grade 11).

Subject	Highest level reached (e.g. 2nd yr univ)	Highest level taught (e.g. G 11)
Chemistry		
Physics		
Physical Science		
(Others)		

Please provide the following information about your teaching.

Number of years	School and province	Subjects taught	Classes taught

Code:………………….………….…

Code:

1. Give one word or term for each of the following description.

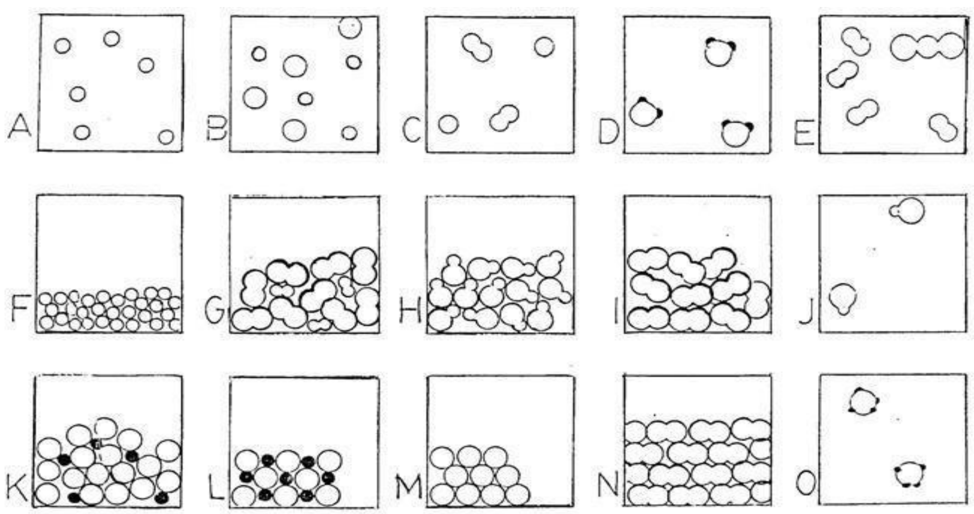
a) A substance that is made of only one kind of atom.
b) A substance made of two or more atoms of different elements chemically bonded.
c) A smallest particle of an element that still retains the chemical properties of that element.
d) A particle that consists of two or more atoms bonded together.
e) A substance that consists of different substances that are not chemically bonded to each other and still retain their original properties.

Answers:

(a)________________________; (b)________________________; (c)________________________

(d)________________________; (e)________________________

2. In the diagrams below say:



a) Which diagram(s) consist(s) of only one element?
b) Which diagram(s) consist(s) of only one compound?
c) Which diagram(s) represent(s) a mixture?
d) Which diagram(s) represent(s) a pure solid?
e) Which diagram(s) represent(s) a pure liquid?
f) Which diagram(s) represent(s) a gas?
g) Which diagram(s) represent a pure substance?
h) Which diagram(s) represent molecules only?

Answers

(a)_____________________; (b)_____________________; (c) _____________________;

(d)_____________________; (e)_____________________; (f)________________________

(g)_____________________; (h)___________________

3. Draw microscopic representations of oxygen as it heated from a solid to a liquid to a gaseous state in the boxes below. Use  to represent a single molecule. Draw 9 molecule s in each box.

Solid

Liquid

Gas

4. Question 1 to 4: are the following statement true (T) or false (F)?
Circle the correct answer and indicate the degree of confidence i.e. 100% sure, not sure or guessing.

a) All molecules of a given pure substance are identical. **T/F**

100% sure	***Sure***	***guess***

b) Between molecules of a substance there is “empty space”. **T/F**

100% sure	***Sure***	***guess***

c) A molecule of a substance in the solid phase has larger mass than a molecule of the same substance in the gaseous phase. **T/F**

100% sure	***Sure***	***guess***

d) The forces of attraction between molecules of naphthalene in the liquid phase are greater than in the solid phase. **T/F**

100% sure	***sure***	***guess***

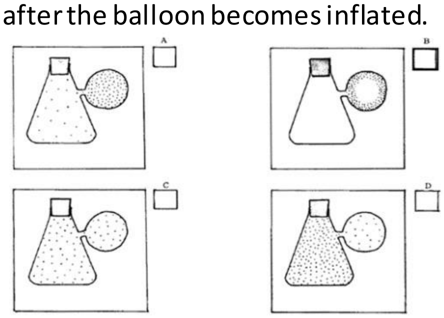
5.

a) Name the sub-atomic particles found in the nucleus of an atom

____

b) A flask containing air was connected to rubber balloon. Then the air in the flask was heated with a flame and the balloon inflated.

Place an X in the square next to the drawing which you think is the best description of the air after the balloon becomes inflated.



c) After many experiments, scientists now think all substances are made up of particles.
Use this idea to answer the question below:
A block of ice is taken out of a freezer at -100^{0}C. Describe what happens to its particles as its temperature rises to -10^{0}C. Draw a diagram to explain what you mean.

d) After many experiments, scientists now think that:

- All things are made of small particle
- These particles move in all directions
- Temperature affects the speed they move
- They exert forces on each other

Use any of these ideas to help answer the following question:
A football is pumped up during the day when it is warm. In the evening when the temperature falls, the football does not feel so hard.
How does this happen? (Assume the football does not leak)

____

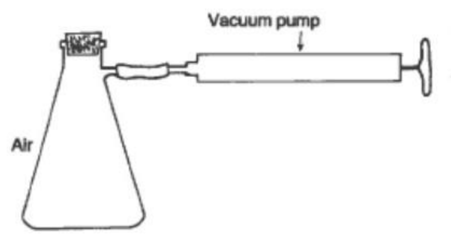
____

____

____

____

e) A one-litre flask containing air and a hand evacuating pump were shown, and the operation and function of the pump were demonstrated. The pump was then connected and operated for a few seconds in order to remove some air from the flask.



Suppose that you had magic eye glasses with which you were able to see the air in the flask. Draw how it would look before and after the vacuum pump was used to remove some of the air.

PARTICULATE NATURE OF MATTER PCK TEST

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SECTION A: BACKGROUND INFORMATION

NAME AND SURNAME: ______________________________ Gender (tick ✓):

Female	Male

HOME province and town: ____

Please fill in details about all post school qualifications. (since you left school.)

Qualification and length of course (e.g. STD - 3yrs)	From (year)	To (year)	Main Subjects

Please provide the highest level reached in your science content subjects studied - i.e. science and maths courses (not education or methodology/didactics courses) and the highest level at which you have taught (e.g. grade 11).

Subject	Highest level reached (e.g. 2nd yr univ)	Highest level taught (e.g. G 11)
Chemistry		
Physics		
Physical Science		
(Others)		

Please provide the following information about your teaching.

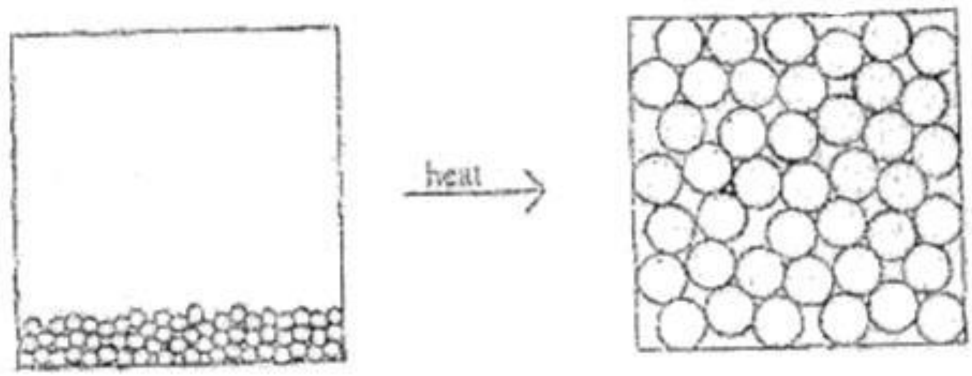
Number of years	School and province	Subjects taught	Classes taught

Code: ……………………………….

Code:

CATEGORY A: LEARNERS' PRIOR KNOWLEDGE

3. Learners in a grade 8 class were asked to represent the change that takes place when a substance is heated. The response Thabo has written on the board is shown below.



How would you comment on Thabo's response as part of an explanation to the rest of the class?

Response A: Thabo's response is incorrect. All substances have small particles called atoms that may combine chemically with each other to form molecules. When substances are heated their molecules do not expand in size. The size of the molecules stays the same.

Response B: Thabo's response is incorrect. When a substance is heated, molecules gain kinetic energy. The molecules will start vibrating and the bonds between them weaken to allow re-arrangement and in some cases allowing the molecules to move away from each other. The molecules themselves do not change in size when heated. It is the re-arrangement of molecules that changes.

Response C: Thabo's response is incorrect. When a substance is heated, a phase change occurs. The molecules of a substance become more free from each other as the bonds are weakened in some cases completely broken. Substances that were originally solids may become liquids and liquids may become gases

Response D: None of the above

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

My choice is Response …..

Water boiling in a kettle

2. When learners were asked to observe and describe what the bubbles are made of when the water in a kettle is boiling, Lwando gave the following written response:

There are large bubbles in the water and these bubbles were made of hydrogen and oxygen because water breaks when boiling to form hydrogen and oxygen.

What response would you write on her script?

CATEGORY B: CURRICULUM AWARENESS

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

3.1 What do you consider to be the four main ideas (main concepts) to be taught about particle nature of matter at Grade 8? Choose from the list provided.

Particles are in constant motion	Substance have subatomic particles
Molecules have forces between each other	Compounds are made up of atoms
Elements are made up of atoms	Atom has a specific structure
Matter is made up of small bits that are called particles	There are different type of small bits of substance with different arrangements
Atoms are smallest particle	Matter is found in different phases
Molecules are made from atoms	Particles of different substances are different
There are different atomic theories	Other
There is empty space between particles	

5.
6.
7.
8.

3.6 In what sequence would you teach the main ideas you have identified above?

3.7 Make a map or a diagram of these four ideas showing how they link to subordinate ideas.

3.8 What other topics in chemistry do you think require the understanding of particle nature for teaching them?

3.9 Why is it important for learners to learn about particle nature of matter?

CATEGORY C: WHAT MAKES THE TOPIC DIFFICULT TO UNDERSTAND?

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

Concept	✓	What exactly makes it difficult?
There is an empty space between particles of matter		
Particles are in constant motion		

Concept	✓	What exactly makes it difficult?
There are different types of small bits of substances.		
Particle explanation for change of state		

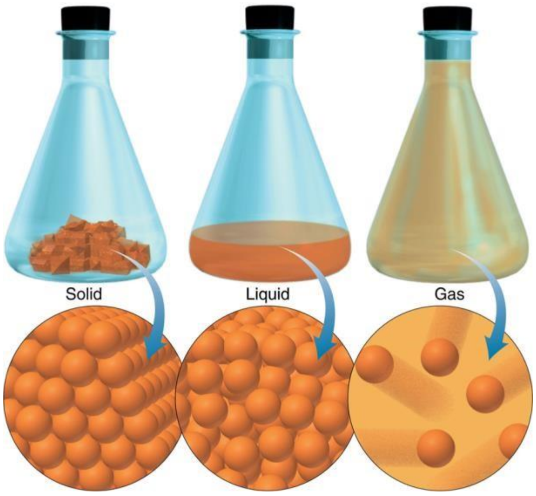
Concept	✓	What exactly makes it difficult?
Particle bombardment with the wall of the container causes pressure in gases		

5. CATEGORY D: REPRESENTATIONS/ MODELS

Phases of Matter

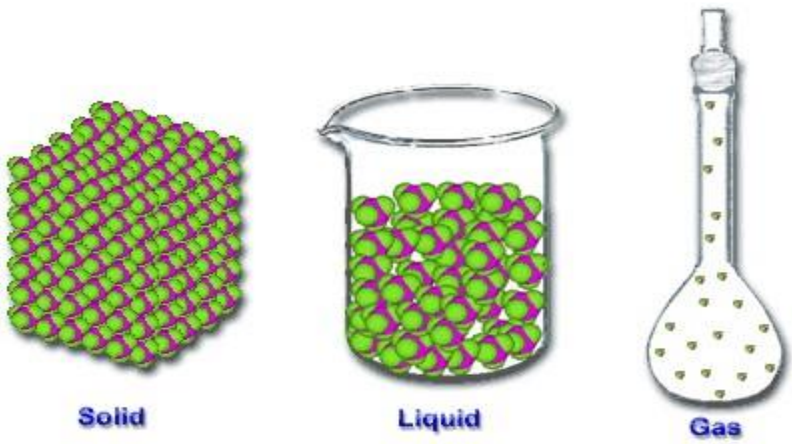
Below are three different representations that can be used for teaching phases of matter. Decide which one(s) you like and complete the table below

Representation 1



Representation 2

Representation 3



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

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

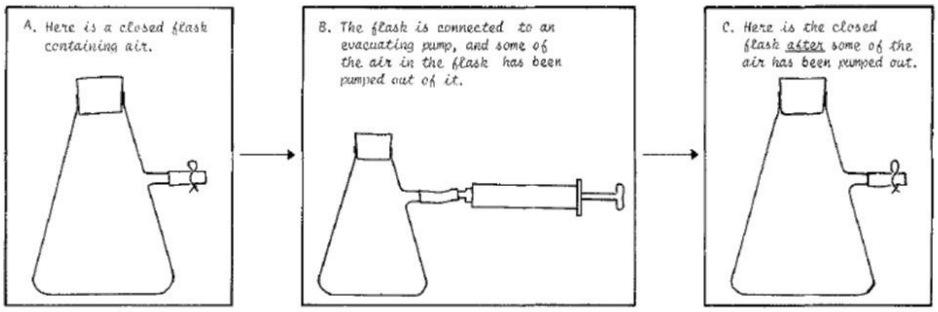
5.2 Which representation do you like most?

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

CATEGORY E: TEACHING STRATEGIES

Particle nature of matter in the gaseous phase

Learners are provided with the pictures below followed by the questions:

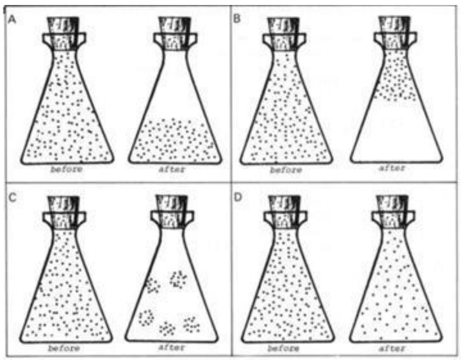


Question

Task 1: Use dots, to show the air particles in the flask in drawing A (above left), as it was before the pump was connected and used.

Task 2: Use dots, to show the air particles remaining in the flask in drawing C (above right), as it is after some of the air was removed by using the pump.

The diagram below shows four learners' responses, A, B, C and D



Following these four leaners' responses, how will you teach a lesson on particle nature of matter in the gaseous phase? Explain fully showing any analogies or representations you would use and how you would deal with their response.

How would you teach this lesson? Consider the following in your answer: what teaching strategy will you follow; what content will you include and the order in which to teach the content, what to rather leave out; are there any ideas that learners typically struggle with, and how you would address these; what representations, pictures, examples or analogies will you use.

Estimate how long it took you in total to complete this assignment: ______________

APPENDIX 4: The Mavhunga & Rollnick (2013) rubric for scoring TSPCK

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

	(1)Limited	(2) Basic	(3) Developing	(4)Exemplary
Teaching Strategies	• No evidence of acknowledgement of student prior knowledge and misconceptions • Lacks aspects of curriculum saliency • Use of representations limited to macroscopic or symbolic scientific symbolic representation	• Acknowledges student misconceptions verbally with no corresponding confrontation strategy • Lacks aspects of curriculum saliency • Use of macroscopic and symbolic representations with no linking explanatory notes	• Considers confirmation/confrontation of student prior knowledge and/or misconceptions • Considers at least one aspect related to curriculum saliency e.g. sequencing or what not to discuss yet or emphasis of important concepts • Uses at least two different levels of representations to enforce understanding.	• Considers student prior knowledge and evidence of confrontation of misconceptions. • Considers at least two aspects related to curriculum saliency: sequencing, what not to discuss yet, emphasis of important conceptual aspects, etc. • Uses either the macroscopic or symbolic representation with sub-microscopic representation to enforce understanding

APPENDIX 5: TSPCK CLASSROOM RUBRIC FOR TSPCK IN ACTION

Type 1: Simple TSPCK Episode	**Type 2: Proficient TSPCK Episode**	**Type 3: Sophisticated TSPCK Episode**
• Evidence of two different TSPCK components interacting evidently and distinguishably in a specific teacher task segment • The TSPCK component interactions maybe interwoven or have a linear sequence structural formation. • Both components work together to support an explanation of a single or a pair of concepts that are related	• Evidence of three different TSPCK components interacting evidently and distinguishably in a specific teacher task segment Or • Evidence of three different TSPCK components interacting, evidently, and distinguishably in a specific teacher task segment, but one component repeating and bringing a different level of explanation that complements the initial emergence. • The TSPCK component interactions maybe interwoven or have a linear sequence structural formation or both • The three components work together to support an explanation of a single or a pair of concepts that are related	• Evidence of four different TSPCK components interacting evidently and distinguishably in a specific teacher task segment Or • Evidence of four different TSPCK components interacting evidently and distinguishably in a specific teacher task segment, with one of the components repeated_more than once or one of the components bringing different levels of sophistication (e.g. representations used at macro, symbolic and submicroscopic levels. • TSPCK component interactions maybe interwoven or have a linear sequence structural formation or both. • All the TSPCK components work together to support an explanation of a single or a pair of concepts that are related

APPENDIX 6: Memorandum for CK test

University of the Witwatersrand Private Bag 3 Wits 2050 Johannesburg sa t+27 11 7173 265 f+275167237

PCK Research group

Contact Person: Prof. Marissa Rollnick

E-mail: Marissa.Rollnick@wits.ac.za

PARTICULATE NATURE OF MATTER TEST-Memo by Nonkanyiso

This info is for research purposes only: your responses will be treated confidentially. Pseudonyms will be used if a need to refer arises. This page will be detached and stored separately.

SECTION A: BACKGROUND INFORMATION

NAME AND SURNAME: ______________________________ Gender (tick✓):

Female	Male

HOME province and town: ____

Please fill in details about all post school qualifications. (since you left high school.)

Qualification and length of course	**From (year)**	**To (year)**	**Main Subjects**

Please provide the highest level reached in your science content subjects studied - i.e. science and maths courses (not education or methodology/didactics courses) and the highest level at which you have taught (e.g. grade 11).

Subject	**Highest level reached (e.g. 2nd yr univ)**	**Highest level taught (e.g. G 11)**
Chemistry		
Physics		
Physical Science		
(Others)		

Please provide the following information about your teaching.

Number of years	**School and province**	**Subjects taught**	**Classes taught**

Code:………………….…….……

Code:

1. Give one word or term for each of the following description.

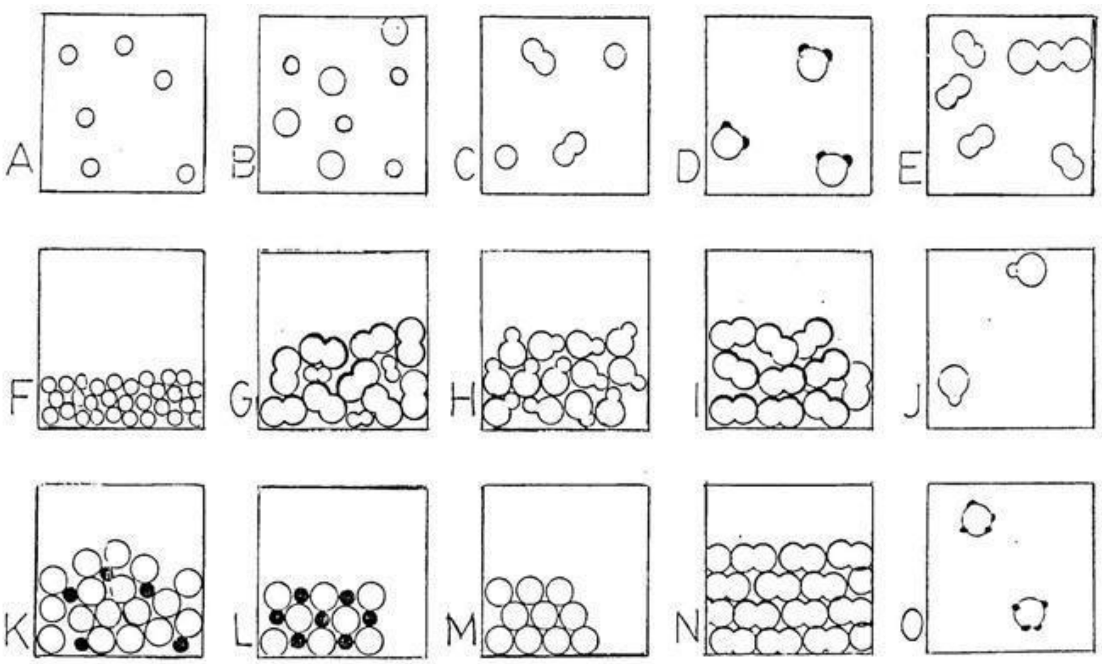
a) A substance that is made of only one kind of atom.
b) A substance made of two or more atoms of different elements chemically bonded.
c) A smallest particle of an element that still retains the chemical properties of that element.
d) A particle that consists of two or more atoms bonded together.
e) A substance that consists of different substances that are not chemically bonded to each other and still retain their original properties.

Answers:

(a) Element (b) Compound (c) Atom

(d) Molecule (e) Mixture

2. In the diagrams below say:



a) Which diagram(s) consist(s) of only one element?
b) Which diagram(s) consist(s) of only one compound?
c) Which diagram(s) represent(s) a mixture?
d) Which diagram(s) represent(s) a pure solid?
e) Which diagram(s) represent(s) a pure liquid?
f) Which diagram(s) represent(s) a gas?
g) Which diagram(s) represent a pure substance?
h) Which diagram(s) represent molecules only?

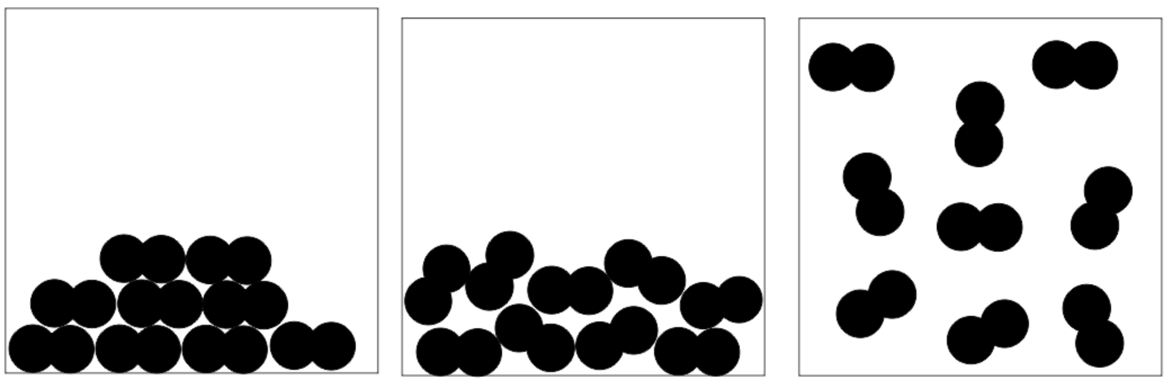
Answers

(a) A, F, I, M, N (b) D, H, J, L, O (c) B, C, E, G, K

(d) L, M, N (e) F, G, H, I, K (f) A, B, C, D, E, J O

(g) A, D, F, H, I, J, L, M, N, O (h) D, E, G, H, I, J, N, O

3. Draw microscopic representations of oxygen as it heated from a solid to a liquid to a gaseous state in the boxes below. Use  to represent a single molecule. Draw 9 molecules in each box.



Solid Liquid Gas

4. Question 1 to 4: are the following statement true (T) or false (F)?
Circle the correct answer and indicate the degree of confidence i.e. 100% sure, not sure or guessing.

a) All molecules of a given pure substance are identical. **T/F**

100% sure	***Sure***	***guess***

b) Between molecules of a substance there is "empty space". **T/F**

100% sure	***Sure***	***guess***

c) A molecule of a substance in the solid phase has larger mass than a molecule of the same substance in the gaseous phase. **T/F**

100% sure	***Sure***	***guess***

d) The forces of attraction between molecules of naphthalene in the liquid phase are greater than in the solid phase. **T/F**

100% sure	***sure***	***guess***

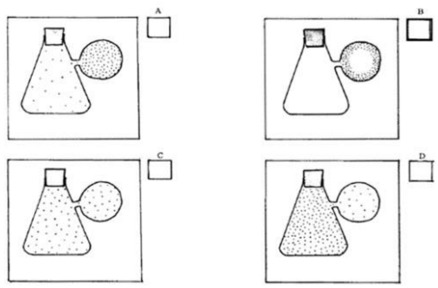
5.

a) Name the sub-atomic particles found in the nucleus of an atom

Protons and Neutrons

b) A flask containing air was connected to rubber balloon. Then the air in the flask was heated with a flame and the balloon inflated.

Place an X in the square next to the drawing which you think is the best description of the air after the balloon becomes inflated.



C.

c) After many experiments, scientists now think all substances are made up of particles.
Use this idea to answer the question below:
A block of ice is taken out of a freezer at -100^0C. Describe what happens to its particles as its temperature rises to -10^0C. Draw a diagram to explain what you mean.

Firstly the water molecules are held together by hydrogen bonds, and will be packed orderly. The molecules will vibrate slightly in their positions. As temperatures increases the molecules will vibrate slightly faster which means every molecule needs a little bit more space which means volume occupied by a fixed amount of molecules will slightly increase-the block of ice will expand.

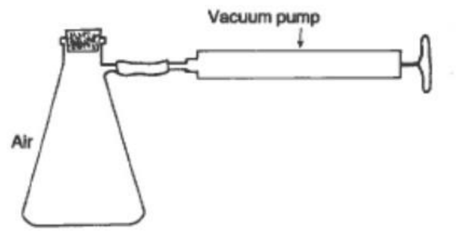
d) After many experiments, scientists now think that:

- All things are made of small particle
- These particles move in all directions
- Temperature affects the speed they move
- They exert forces on each other

Use any of these ideas to help answer the following question:
A football is pumped up during the day when it is warm. In the evening when the temperature falls, the football does not feel so hard.
How does this happen? (Assume the football does not leak)

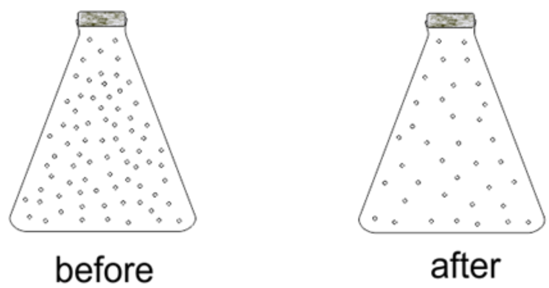
In the evening, the temperature drops, the energy from gas particles inside the ball will now be transferred into the surroundings causing the average speeds of molecules to drop as they have less energy to move and less collisions with the inside of the ball, and thus lowering the p ressure which causes the ball to feel deflated even though no gad was lost.

e) A one-litre flask containing air and a hand evacuating pump were shown, and the operation and function of the pump were demonstrated. The pump was then connected and operated for a few seconds in order to remove some air from the flask.



Suppose that you had magic eye glasses with which you were able to see the air in the flask. Draw how it would look before and after the vacuum pump was used to remove some air.

Before some of the air is removed, there will be no particles in the vacuum pump, all particles will be in the flask. After removal of some of the air, there will be equal spreading of particles throughout the flask and syringe.



APPENDIX 7: Group 1 Completed CoRes of teachers

GROUP 1

Student Misconceptions	
What are the big ideas for the topic?	Particles are in constant motion.
What are the typical student misconceptions on this big idea?	They do not see the movement of particles in solids, only in liquids and gases.
CURRICULAR SALIENCY	
What are the big ideas for the topic?	Particles are in constant motion
What do you intend the learners to know about this big idea?	That even in solids the particles are moving, but in constant motion This is because they are closely packed together. This arrangement will change when the speed is changing ie when heat is added.
Why is it important for learners to know this big idea?	Then the learners will be able to interprete the causes and relate them on their living
What concepts need to be taught before teaching this big idea?	The learners should know the particle arrangement, size remain, (in all these phases of matter)

What else do you know about this big idea (that you do not intend learners to know yet)?	-Use of relevant examples within their level. -Use of examples in their environment.
Teaching Strategies	
What effective teaching strategies would you use to teach this idea?	- Use of practical model
What questions would you consider important to ask in your teaching strategies?	Compare, how, Show
Representations	
What representation would you use in teaching strategies	As a teacher, I use teaching aid and posters
Assessment	
What ways would you use to assess understanding of learners	-Investigation -Drawing to demonstrate -Making of models -Test

Reflections	
What aspects of planning and teaching this big idea would you like to reflect on	The learners now could be able to differentiate And to know that there are spaces b/t particles, particles don't change

APPENDIX 8: Group 2 Completed CoRes of teachers

GROUP 2

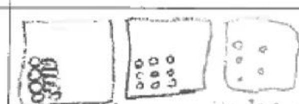
Student Misconceptions	
What are the big ideas for the topic?	Patricles are in constant motion
What are the typical student misconceptions on this big idea?	Solid paticles do not move • particles melt in the case of change of state • Paticles will only move when heat is applied
CURRICULAR SALIENCY	Movement of paticles
What are the big ideas for the topic?	
What do you intend the learners to know about this big idea?	• Learners have to understand: _re-arrangement of paticles due to temperature increase or decrease. • Paticles do not melt only the force holding them together • Particles keep moving even on cold or temperature
Why is it important for learners to know this big idea?	• Paticles are the same whether in solid, liquid or gas • Other paticles have strong forces holding them together (particles of different substances behave differently)
What concepts need to be taught before teaching this big idea?	• Phases of matter • Concepts like: Melting, evaporation condensation; sublimation, solidifi cation

What else do you know about this big idea (that you do not intend learners to know yet)?	Sublimation .Different types of forces
Teaching Strategies	
What effective teaching strategies would you use to teach this idea?	Practical demonstration Videos Representation
What questions would you consider important to ask in your teaching strategies?	Prior knowledge .Interest arousing questions .Reasoning challenging question knowledge display
Representations	
What representation would you use in teaching strategies	Start with macroscopic the follow.
Assessment	
What ways would you use to assess understanding of learners	Use representations for reasoning knowledge testing questions Case study

Reflections	
What aspects of planning and teaching this big idea would you like to reflect on	Some representations will need more explanation or practical demonstration or video to give clarity as some can easily distort.

APPENDIX 9: Group 3 Completed CoRes of teachers

GROUP 3

Student Misconceptions	
What are the big ideas for the topic?	Matter is made up of small bits that are called particles
What are the typical student misconceptions on this big idea?	They misunderstand these concepts, particles, atom, molecule, element.
CURRICULAR SALIENCY	
What are the big ideas for the topic?	 There is a misconception mass of the particles (density)
What do you intend the learners to know about this big idea?	They should know that the size, number does not change only there are air spaces in between the particles.
Why is it important for learners to know this big idea?	Now they can be able to compare and differentiate these particles.
What concepts need to be taught before teaching this big idea?	First introduce 'Matter'

What else do you know about this big idea (that you do not intend learners to know yet)?	Teaching them 'elements' (periodic table)
Teaching Strategies	
What effective teaching strategies would you use to teach this idea?	- Practical model (ice blocks water, boiling water in a kettle)
What questions would you consider important to ask in your teaching strategies?	- Compare - How - Demonstration - Drawing comparing in tables - Videos
Representations	
What representation would you use in teaching strategies	- Posters - Teaching aids, drawing
Assessment	
What ways would you use to assess understanding of learners	- Investigation - Assignment - Test - Classwork

Reflections	
What aspects of planning and teaching this big idea would you like to reflect on	learners should know that there are spaces in between the particles.

APPENDIX 10: Group 4 Completed CoRes of teachers

1 Misconceptions	~~Matter is~~ Particles of different substances are different. Learners cannot see these small bits of substances and cannot see the arrangement
2 What do you intend learners to know about this big idea	Make use of representation like diagram showing the different phases with arrangement of bits
3 Why is it important for learners to know this big idea	For learners to have an understanding of these single units / bits which take us to elements and compounds.
4 What concepts to be taught before	Matter and its different properties and it exists in phases and to what happen in each phase in terms of arrangement of particles
What else do you know (that you intend learners not to know)	They do not know that these bits can combine to form other substances that behave differently eg H_2O
What effective teaching strategies would you use to teach	Videos, Models
What questions would you consider important	Compare (movement arrangement)

What representation would you use in teaching this big idea — posters, Drawings and tabulation

What ways would you use to assess understanding of learners — A practical task
- Written task with drawings

What aspect of planning and teaching this big idea would you like to reflect on
- Get the knowledge that there are spaces between the small bits (particles)
- They can move
- Temperature has an effect on the movement of these particles
- They also differ in their arrangement
-

APPENDIX 11: Completed TSPCK Instrument by Teacher Nosipho

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PCK Research group

Contact Person; Prof. Marissa Rollnick

E-mail: Marissa.Rollnick@wits.ac.za

PARTICULATE NATURE OF MATTER DIAGNOSTIC TOOL

PARTICULATE NATURE OF MATTER TEST

This info is for research purposes only: your responses will be treated confidentially. Pseudonyms will be used if a need to refer arises. This page will be detached and stored separately.

SECTION A: BACKGROUND INFORMATION

NAME AND SURNAME: V. V. AROSI Gender (tick✓):

Female ✓	Male

HOME province and town: E. CAPE MTHATHA

Please fill in details about all post school qualifications. (since you left high school.)

Qualification and length of course	From (year)	To (year)	Main Subjects
PTC	1979	1980	All primary Subjects
Dip Ed Sec	1995	1996	Biology & English
B. Ed Senior Phase	2000	2002	Maths & Science Sen Phase

Please provide the highest level reached in your science content subjects studied - i.e. science and maths courses (not education or methodology/didactics courses) and the highest level at which you have taught (e.g. grade 11).

Subject	Highest level reached (e.g. 2nd yr univ)	Highest level taught (e.g. G 11)
Chemistry	2nd year University	Grade 09
Physics	2nd year University	Grade 09
Physical Science	2nd University	Grade 09
(Others)		

Please provide the following information about your teaching.

Number of years	School and province	Subjects taught	Classes taught
12 yrs	Ramohlakoana	Maths	General Science
8 yrs	MBANDULI VILLAGE	Maths, Natural	Sciences
10 yrs	MBANDULI JSS	NS ; ENGLISH	LO

Code: ....

WSoE

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marang

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PCK Research group

Contact Person: Prof. Marissa Rollnick

E-mail: Marissa.Rollnick@wits.ac.za

PARTICULATE NATURE OF MATTER DIAGNOSTIC TOOL

PARTICULATE NATURE OF MATTER TEST

This info is for research purposes only: your responses will be treated confidentially. Pseudonyms will be used if a need to refer arises. This page will be detached and stored separately.

SECTION A: BACKGROUND INFORMATION

NAME AND SURNAME: V. V. AROSI Gender (tick✓):

Female	Male
✓	

HOME province and town: E. CAPE MTHATHA

Please fill in details about all post school qualifications. (since you left high school.)

Qualification and length of course	From (year)	To (year)	Main Subjects
PTC	1979	1980	All primary Subjects
Dip Ed Sec	1995	1996	Biology & English
B. Ed Senior Phase	2000	2002	Maths & Science Sen phase

Please provide the highest level reached in your science content subjects studied - i.e. science and maths courses (not education or methodology/didactics courses) and the highest level at which you have taught (e.g. grade 11).

Subject	Highest level reached (e.g. 2nd yr univ)	Highest level taught (e.g. G 11)
Chemistry	2nd year University	Grade 09
Physics	2nd year University	grade 09
Physical Science	2nd University	Grade 09
(Others)		

Please provide the following information about your teaching.

Number of years	School and province	Subjects taught	Classes taught
12 yrs	Ramchlakana	Maths	General Science
8 yrs	MBANDULI VILLAGE	Maths, Natural	Sciences
10 yrs	MBANDULI J.S.S	NS ; ENGLISH	LO

Code: ……………………………

1. Give one word or term for each of the following description.

Code:

(a) A substance that is made of only one kind of atom.

(b) A substance made of two or more atoms of different elements chemically bonded.

(c) A smallest particle of an element that still retains the chemical properties of that element.

(d) A particle that consists of two or moreatoms bonded together.

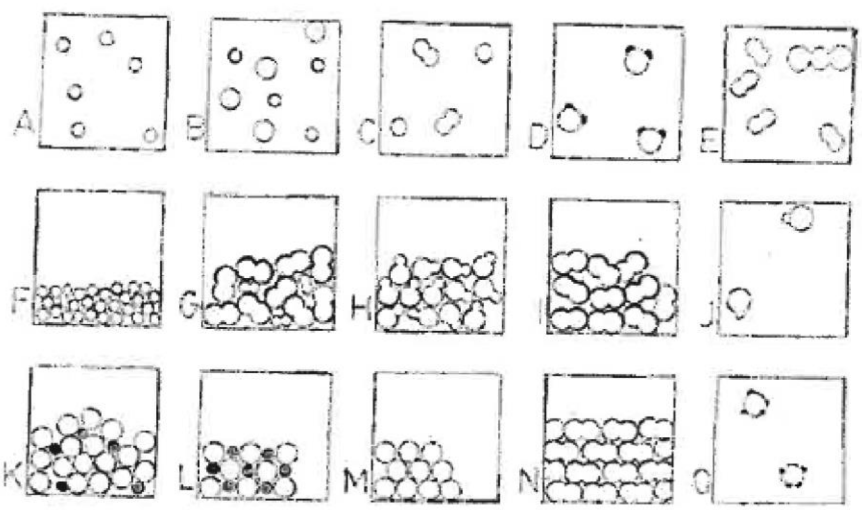
(e) A substance that consists of different substances that are not chemically bonded to each otherand still retain their original properties.

Answers:

(a) Element ;(b) Compound ; (c) Atom

(d) molecule ; (e) Mixture

2. In the diagrams below say:



(a) Which diagram(s) consist(s) of only one element?

(b) Which diagram(s) consist(s) of only one compound?

(c) Which diagram(s) represent(s) a mixture?

(d) Which diagram(s) represent(s) a pure solid?

(e) Which diagram(s) represent(s)a pure liquid?

(f) Which diagram(s) represent(s) a gas?

(g) Which diagram(s) represent a pure substance?

(h) Which diagram(s) represent molecules only?

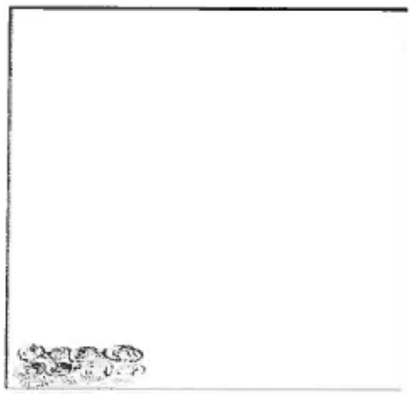
Answers

(a) A ; (b) D ; (c) B, C & E ;

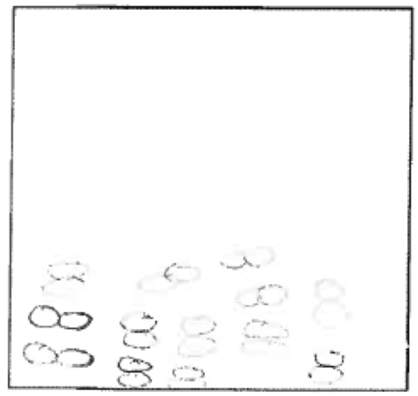
(d) ~~A~~ F,M,N ; (e) H & I ; (f) O

(g) A ; (h) I, H & N

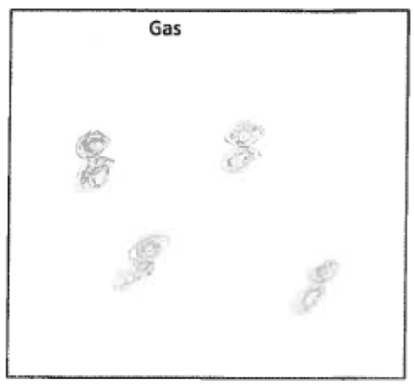
3. Draw microscopic representations of oxygen as it heated from a solid to a liquid toa gaseous state in the boxes below.  Useto represent a single molecule. Draw 9 molecules in each box.



Solid



Liquid



4. Question 1 to 4: are the following statement true (T) or false (F)?
Circle the correct answer and indicate the degree of confidence i.e. 100% sure, not sure or guessing.

(1) All molecules of a given pure substance are identical. **T/F**

100% sure	*Sure*	*guess*

(2) Between molecules of a substance there is "empty space".**T/F**

100% sure	*Sure*	*guess*

(3) A molecule of a substance in the solid phase has largermass than a molecule of the same substance in the gaseous phase.T/F

100% sure	Sure	guess

(4) The forces of attraction between molecules of naphthalenein the liquid phase are greater than in the solid phase.T/F

100% sure	sure	guess

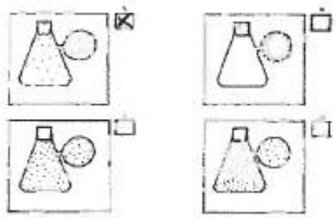
5.

(a) Name the sub-atomic particles found in the nucleus of an atom

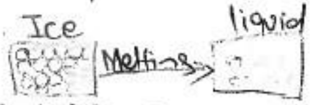
Protons a neutrons

(b) A flask containing air was connected to rubber balloon. Then the air in the flask was heated with a flame and the balloon inflated.

Place an X in the square next to the drawing which you think is the best description of the air after the balloon becomes inflated.



(c) After many experiments, scientists now think all substances are made up of particles. Use this idea to answer the question below:
A block of ice is taken out of a freezer at -100^{0}C. Describe what happens to its particles as its temperature rises to -10^{0}C. Draw a diagram to explain what you mean.



particles are closely/tightly packed together

Particles break the forces that hold breaking them together and start moving then become liquid

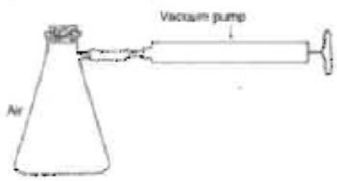
(d) After many experiments, scientists now think that:

- All things are made of small particle
- These particles move in all directions
- Temperature affects the speed they move
- They exert forces on each other

Use any of these ideas to help answer the following question:
A football is pumped up during the day when it is warm. In the evening when the temperature falls, the football does not feel so hard.
How does this happen? (Assume the football does not leak)

During the day when it is warm air particles inside the ball are moving breaking the forces holding them together and pushing the walls of the ball (expand)
Evening: They come together and we say they contract)

(e) A one-litre flask containing air and a hand evacuating pump were shown, and the operation and function of the pump were demonstrated. The pump was then connected and operated for a few seconds in order to remove some air from the flask.



Suppose that you had magic eye glasses with which you were able to see the air in the flask. Draw how it would look before and after the vacuum pump was used to remove some of the air.

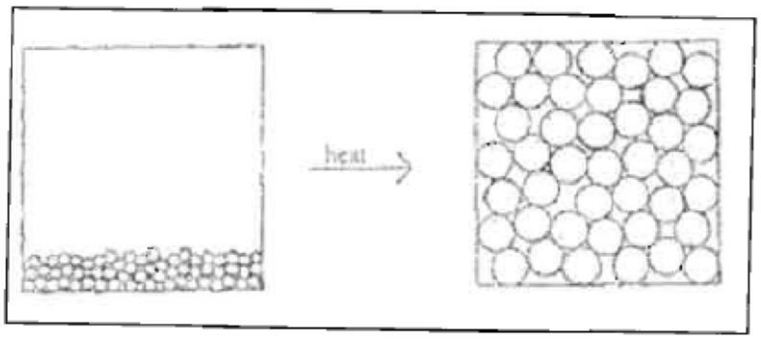
Before

After

Code:

CATEGORY A: LEARNERS' PRIOR KNOWLEDGE

1. Learners in agrade 8 class were asked to represent the change that takes place when a substance is heated. The response Thabohas written on the boardis shown below.



How would you comment on Thabo's response as part of an explanation to the rest of the class?

Response A: Thabo's response is incorrect. All substances have small particles called atoms that may combine chemically with each other to form molecules. When substances are heated their molecules do not expand in size. The size of the molecules stays the same.

Response B: Thabo's response is incorrect. When a substance is heated, molecules gain kinetic energy. The molecules will start vibrating and the bonds between them weaken to allow re-arrangement and in some cases allowing the molecules to move away from each other. The molecules themselves do not change in size when heated. It is the re-arrangement of molecules that changes.

Response C: Thabo's response is incorrect. Whena substance is heated, a phase change occurs. The molecules of a substance become more free from each other as the bonds are weakened in some cases completely broken. Substances that were originally solids may become liquids and liquids may become gases

Response D: None of the above

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

My choice is Response ...B

(2)

Water boiling in a kettle

2. When learners were asked to observe and describe what the bubbles are made of when the water in a kettle is boiling, Lwando gave the following written response:

There are large bubbles in the water and these bubbles were made of hydrogen and oxygen because water breaks when boiling to form hydrogen and oxygen.

What response would you write on her script?

Bubbles are the evidence of the movement of water particles as they have gained kinetic energy and the kinetic energy causes them to move faster and therefore opening spaces between them.

(2)

CATEGORY B: CURRICULUM AWARENESS

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

3.1 What do you consider to be the four main ideas (main concepts) to be taught about particle natureof matter at Grade 8? Choose from the list provided.

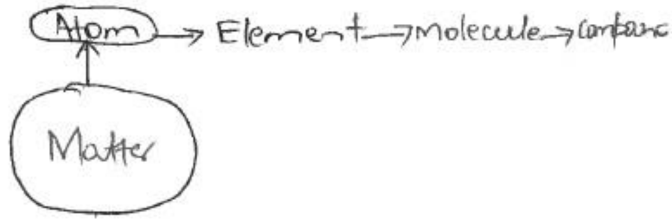
Particles are in constant motion	Substance have subatomic particles
Molecules have forces between each other	Compounds are made up of atoms
Elements are made up of atoms	Atom has a specific structure
Matter is made up of small bits that are called particles	There are different type of small bits of substance with different arrangements
Atoms are smallest particle	Matter is found in different phases
Molecules are made from atoms	Particles of different substances are different
There are different atomic theories	Other
There is empty space between particles	

1. Matter is made up of small particles
2. Atoms are smallest particles
3. Elements are made of atoms
4. Molecules are made from atoms

3.2 In what sequence would you teach the main ideas you have identified above?

The sequence above

3.3 Make a map or a diagram of these four ideas showing how they link to subordinate ideas.



3.4 What other topics in chemistry do you think require the understanding of particle nature for teaching them?

Expansion a Contraction of substances
Density of substances like fuel used in different areas (in land or along the coast)
Different boiling points due to density of the air.

3.5 Why is it important for learners to learn about particle nature of matter?

- When they design objects they should give the allowance of expansion & contraction
- When filing the containers like petrol tanks they need to leave the space for movement of particles during hot days
- When packing objects etc

(1)

CATEGORY C: WHAT MAKES THE TOPIC DIFFICULT TO UNDERSTAND?

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

Concept	✓	What exactly makes it difficult?
There is an empty space between particles of matter	✓	It is too abstract and its not easy to demonstrate it practically especial with solids & liquids
Particles are in constant motion	✓	With solids, there is no evidence of moving particles especially with non-metal solids (wood).
There are different types of small bits of substances.		
Particle explanation for change of state		

Concept	✓	What exactly makes it difficult?
Particle bombardment with the wall of the container causes pressure in gases	✓	It is too abstract

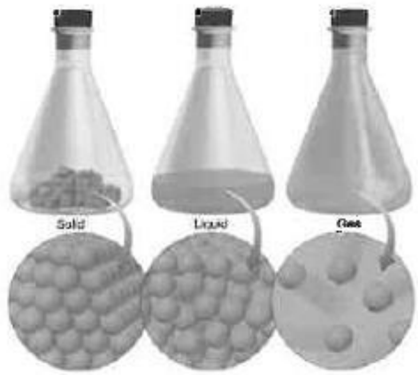
(2)

5. CATEGORY D: REPRESENTATIONS/MODELS

Phases of Matter

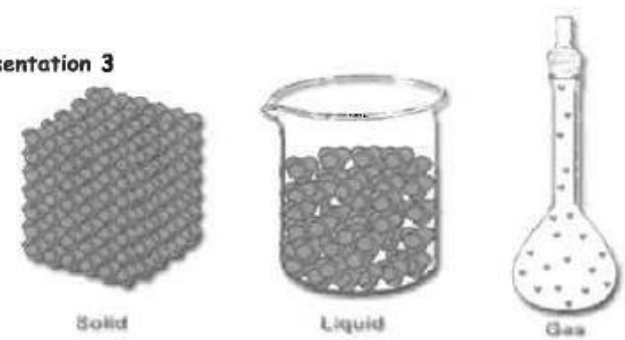
Below are three different representations that can be used for teaching phases of matter. Decide which one(s) you like and complete the table below

Representation 1



Representation 2

Representation 3



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

Representation No.	What I Like	What I do not like
1		
2 ✓	• The example is about what they know - they know ice is frozen water, they know is [illegible] changes to liquid when out of freezer for a long time. They see the water boiling everyday. This is all familiar	Usually the terms used for evaporated water: like water in gas form.
3 ✓	• It gives the clear picture of how particles are arranged in a solid substance.	I am not able to do practical demonstration which will show the particles changing from one phase to the other

5.2 Which representation do you like most?

Representation 2

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

• Using ice blocks from the school freezer and explain the terms involved like frozen, melting, solid, liquid

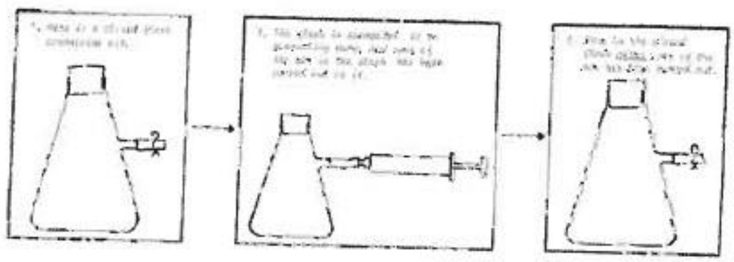
• learners observe as ice melts changing from solid to liquid and they answer the questions asked.

• We boil the very same water until the container is empty proving the evaporation of water ie changing from liquid to gas.

CATEGORY E: TEACHING STRATEGIES

Particle nature of matter in the gaseous phase

Learners are provided with the pictures below followed by the questions:

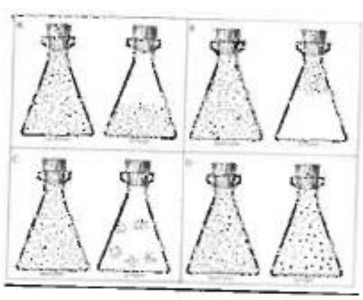


Question

Task 1: Use dots, to show the air particles in the flask in drawing A (above left), as it was before the pump was connected and used.

Task 2: Use dots, to show the air particles remaining in the flask in drawing C (above right), as it is after some of the air was removed by using the pump.

The diagram below shows four learners' responses, A, B, C and D



Following these four leaners' responses, how will you teach a lesson on particle nature of matter in the gaseous phase? Explain fully showing any analogies or representations you would use and how you would deal with their response.

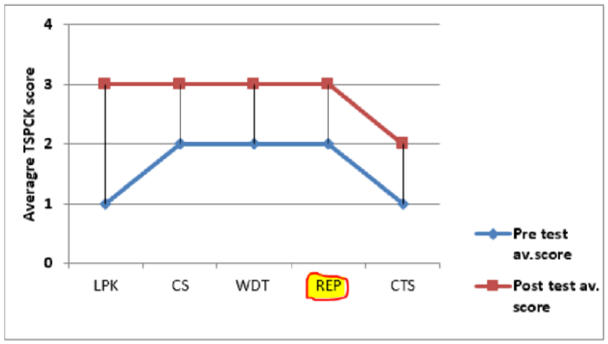
How would you teach this lesson? Consider the following in your answer: what teaching strategy will you follow; what content will you include and the order in which to teach the content, what to rather leave out; are there any ideas that learners typically struggle with, and how you would address these; what representations, pictures, examples or analogies will you use.

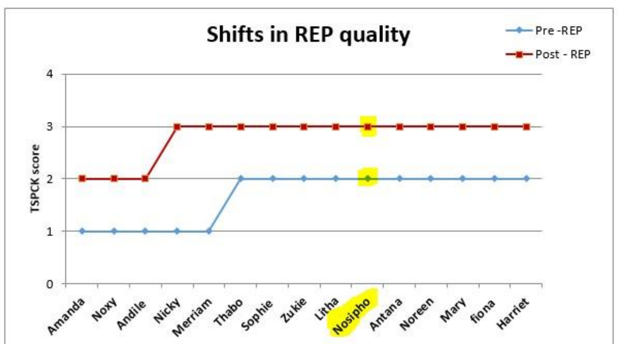
①

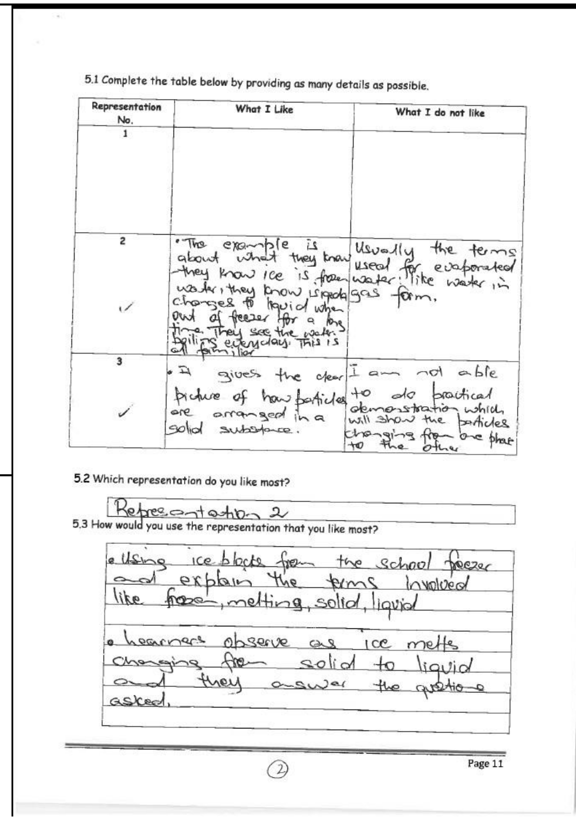
Estimate how long it took you in total to complete this assignment: ____________

APPENDIX 12: Analysis for example of average shift experienced by OFT's in representations using extract from teacher Nosipho

TSPCK Score	Extract from pre-test	Extract from post-test







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

Representation No.	What I Like	What I do not like
1		
2 ✓	• The example is about what they know – they know ice is frozen water, they know is [illegible] changes to liquid when out of feezer for a long time. They see the water boiling everyday. This is all familiar	Usually the terms used for evaporated water: like water in gas form.
3 ✓	• It gives the clear picture of how particles are arranged in a solid substance.	I am not able to do practical demonstration which will show the particles changing from one phase to the other

5.2 Which representation do you like most?

Representation 2

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

• Using ice blocks from the school feezer and explain the terms involved like frozen, melting, solid, liquid

• learners observe as ice melts changing from solid to liquid and they answer the questions asked.

②

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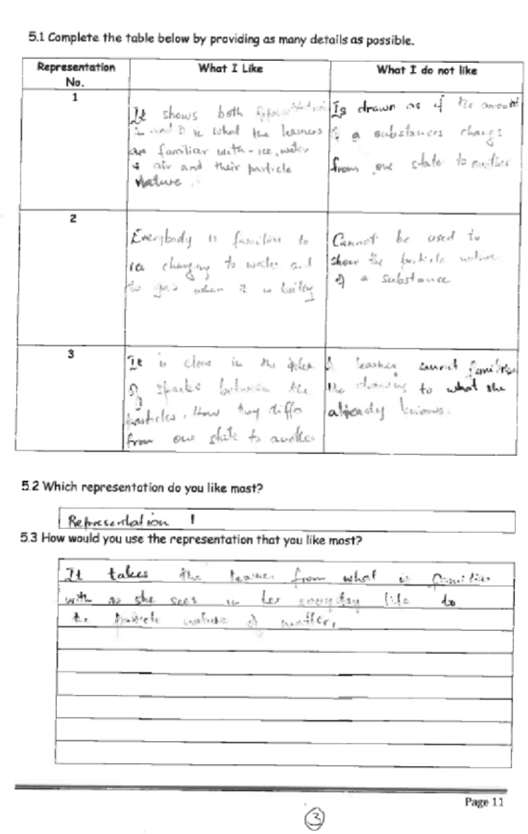

5.1 Complete the table below by providing as many details as possible.

Representation No.	What I Like	What I do not like
1	It shows both [illegible] and it is what the learners are familiar with - ice, water & air and their particle nature	Is drawn as if the amount of a substances changes from one state to another
2	Everybody is familiar to ice changing to water and to gas when it is boiling	Cannot be used to show the particle nature of a substance
3	It is clear in the idea of spaces between the particles, how they differ from one state to another	[illegible] learner cannot familiarise the drawing to what she already knows.

5.2 Which representation do you like most?

Representation 1

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

It takes the learner from what is familiar with as she sees in her everyday life to the particle nature of matter.

③

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Figure 5.11: Teacher Nosipho's responses in the Pre and post TSPCK tests in the component of representations

Example 4: Pre and post TSPCK test scores in the component of Representations

In the Figure above teacher Nosipho has acknowledged two representations as she mentions what she liked about Representation 2 and 3. In representation 2, Teacher Nosipho mentioned that the concepts represented were what her learners were familiar with, particularly how ice water changes from to solid to liquid when out of freezer for a long time. The teacher added that learners saw boiling water everyday in their lives. The teacher further added that she also liked representation 3 because *"it gives the clear picture of how particles are arranged in a solid substance".* In both representations chosen by teacher Nosipho, the reasons explained do not get into deeper insights for teaching particulate nature of matter. There is little mention of how these representations would assist in understanding the topic at hand. The teacher added that learners saw boiling water everyday in their lives. The teacher further added that she also liked representation 3 because *"it gives the clear picture of how particles are arranged in a solid substance".* In both representations, teacher Nosipho does not get into deeper insights for teaching particulate nature of matter using these representations.

Furthermore, the reasoning she suggested for her choice of representation 2 also does not show how she would conduct a lesson around the concept depicted by this representation and so how this representation would be useful in her teaching. This statement shows how Nosipho would use representation 2 to teach "*using ice blocks from the school freezer and explain the terms involved like freezing, melting, solid, liquid, Learners observe ice melts changing from solid to liquid and they answer the question asked.* Teacher Nosipho does not speak conceptually with any specific concepts that she would use to teach through use of the representation, her reasoning remains generic thus awarded a score of 2. It is important to note however that, OFTs knowledge of this knowledge component was not as poor as one might have imagined for teachers teaching out-of-field. OFTs were able to recognize each of the representations even though this was done at a very generic level. It is evident therefore that, at the beginning of the intervention, OFTs were generic in their use of representations.

- **TSPCK development (Representations) post the intervention**

However, Nosipho's written responses post the intervention demonstrated developing TSPCK, in terms of both the knowledge demonstrated for different types of representations as well as their use of these representations. Furthermore, there is evidence of drawing from other TSPCK components to provide detailed use of these **representations** in formulating teacher explanations at this stage of the intervention. The reasons provided by teachers are related to **learner prior knowledge** and cautioning about possible misconceptions that each of the representations might bring. This understanding gives teachers' planning an opportunity to formulate strategies that may assist in dealing with these possible misconceptions. Teacher Nosipho's post intervention responses also revealed clarity of mind in terms of articulating the manner they would use the representation of their choice to explain the concept of particle arrangement at different phases which means the teachers is drawing from her knowledge of **curricular saliency.** Furthermore, teacher Nosipho's choice of one representation she would choose in teaching provides details of how this representation can be used to explain arrangement of particles at different phases. Teacher Nosipho stated that the representation of her choice *"it takes learners from what is familiar with as she sees in her everyday life to particulate nature of matter*". This was additional to the fact that teacher Nosipho mentioned that she liked representation 1 for the fact that it took into consideration both representations of concepts which learners were familiar with (ice, water, air) and their respective particle nature explanations

It is evident from the statement above that Nosipho was engaging the representation of her choice deeper through the concepts which needs to be developed for learners' understanding at Grade 8. There are relevant specifications and articulations which draw deeper from the knowledge of **curricular saliency** to give a clear lesson on what the representation would be useful at in fostering development of these concepts in teaching particulate nature of matter. There were higher component interactions emerging in teacher responses post the intervention. Even the choices that these teachers made at this stage were more acknowledging to that fact that the topic of particle nature of matter is the main reason for teaching the topic as compared to the beginning of the intervention where teachers were comfortable with ice → liquid water → water vapor explanations which only focused at one level of matter which does not explain the particle nature of it.

The written response of teacher Nosipho gives evidence of interactive use of two and more TSPCK components used simultaneously to plan to teach phases of matter specifically zooming to specific content which talks to the particle nature of matter, thus awarded a score of 3 and this was the dominating trend in the component of representations thus OFTs achieved an average score of 3 post the intervention.

APPENDIX 13: Analysis for average shift experienced by OFT's in CTS using extract from teacher Sophie

Example 5: Pre (post) TSPCK test scores in the component of Conceptual Teaching Strategies

Finally, when probing teachers' knowledge on teaching stategies, teacher Sophie was not able to give a written response on how she would devise a teaching strategy based on the question asked. The teacher was awarded a score of 1 in this test to reflect a teacher with limited TSPCK.

As a way of presenting evidence and example of a teacher responses showing the process of how emerging developing TSPCK in conceptual teaching strategies looks like from the qualitative account. Group responses from the activities which teacher Sophie worked with during the intervention as a way of examining their TSPCK as intervention was proceeding are given in Figure 5.13 below, Sophie's group argued that the effective teaching strategy which they would use to teach the big idea *"particles are in constant motion* was "*practical model (ice block & water: boiling water in a kettle"* and further stated that the questions they would consider important to ask in their teaching strategies were *"compare, how, demonstrations, drawing comparing in tables, videos".* In this group, teachers' incorporation of TSPCK components is limited to use of one component and both groups only had representations in their explanations without any curricular awareness or deeper evidence of understanding the concepts which they would teach when using the representations proposed.

This however changed in the post tests as teacher Sophie stated in her teaching strategy that she would " *At the beginning the flask was full of particles after the application of a pump, some partcles will be taken from the flask to the pump then the remaining particles will try to occupy the flak as gases travel faster than any other phase. ….gaseous particles travel fast since they ismore space fo example on a windy day when opens the door the wind will move faster into the room to try and feel the space….amnother example about gases it is easy to smell a desirable and udesirable smell".* Teacher Sophie is trying to use examples and explanations in her teaching strategy however as much as she tried to adress the misconception, her explanation lacks specific aspects of curricular saliency needed to confront the misconception and to further provide correct content knowledge to establish correct understanding. Teacher Sophie was then awarded a score of 2 prior the intervention as her witten reposne is a reflection basic quality of TSPCK. This is an example of a teacher response which reflected a 1 category jump but still in the lower levels of TSPCK.

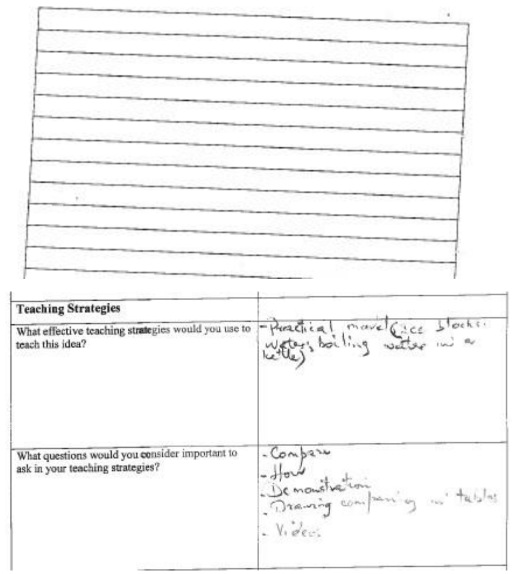
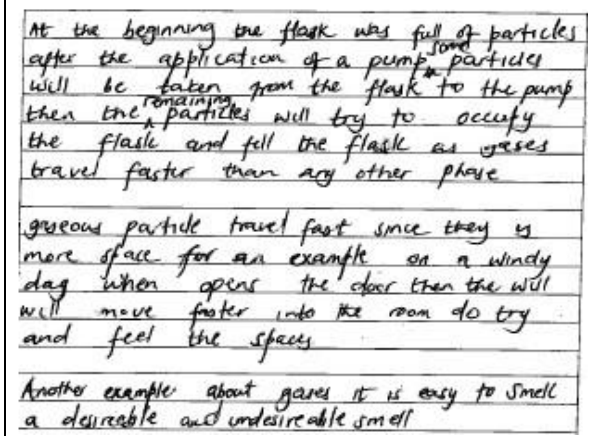
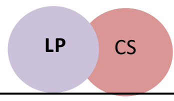
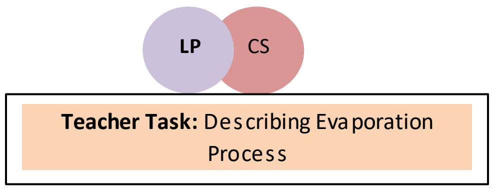
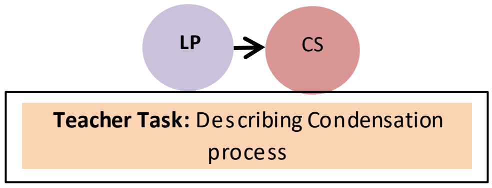
<table>
<tr><th>TSPCK Score</th><th>Extract from pre-test</th><th>Extract from post-test</th></tr>
<tr>
<td>
</td>
<td>
Teaching Strategies
What effective teaching strategies would you use to teach this idea? | - Practical model (ice blocks water, boiling water in a kettle)
What questions would you consider important to ask in your teaching strategies? | - Compare - How - Demonstration - Drawing comparing in tables - Videos</td>
<td>
At the beginning the flask was full of particles after the application of a pump some particles will be taken from the flask to the pump then the remaining particles will try to occupy the flask and fill the flask as gases travel faster than any other phase
gaseous particle travel fast since they is more space for an example on a windy day when opens the door then the will will move faster into the room do try and feel the spaces
Another example about gases it is easy to Smell a desireable and undesireable smell</td>
</tr>
</table>

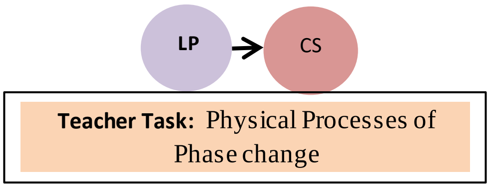
Figure 5.13: Teacher Sophie's responses in the Pre (post) TSPCK tests in the component of teaching strategies

APPENDIX 14: Analysis of teacher Amanda's lesson 2 (pre-intervention)

Lesson 2	
0-3 min: Addressing a learner misconception on phase change vs change in the amount of substance *Teacher: if I'm taking away some water and I am having this size (half bottle of water) of water and put it on the freezer, will I have the full size of this bottle/ ice?* *Learners: No* *Teacher: Why? Why? Why, why? Why? Ok, to make the water an ice does not mean you have changed the mass of the water. The only thing you have changed is the stage or the phase. If you making an ice doesn't mean you are changing the amount, if you're changing the stage you not changing the amount. The amount will remain the same. If you/ I've poured the quarter of the bottle and I want to make an ice. What will be the size of my ice class? What will be the size of my ice? If I've put this (quarter size of water) size of water in freezer? What will be the size of my ice? What will be the size of my ice? At the beginning, it was the full then it was three quarters and now it's a quarter. A bottle of water and I'm boiling it, how much am I going to have to boiled water? I am having a full bottle of water- If I am boiling full bottle of water- if am boiling the full bottle of water? Yes MaZandie* *Learner: The water will not change the size* *Teacher: Yes very good, the water will not change the size*	**Comment:** In this teaching segment, the teacher **In-depth Qualitative analysis:** **Teacher Amanda's Role**: The teacher asked learners changing the phase of liquid water to solid (ice) would change the amount of water. **Learner's Role:** the students responded with a No and when the teacher asked the reason they could not answer (LP) **Teacher Amanda's Role:** Teacher Amanda is addressing a commonly known misconception on the topic of particle nature of matter as she explains that the change of phase does not mean change in the amount of substance undergoing phase change. In this discussion teacher, Amanda is using LP/CS to address an understanding that phase change does not mean change in the amount. The TSPCK episode resulting from this discussion can be mapped as follows:  **Teacher Task:** Explaining phase change vs change in the amount of substance
4 -13min: Describing Evaporation Process *Teacher: but if I keep on boiling the water until it's getting to this stage. Do you think the water will remain the same? Do you think the water will remain the same? If I have too much heat now- my variable, an added more variable in temperature.* *Glass of water, you pour it on the pot and you've got too much fire. Do you think after 30 minutes when you go and look you will have same amount of water?* *Learners: No* *Teacher: Why? Will the water increase or decrease? Will the water increase or decrease? If you boiling the water, do you think the water will increase or decrease? Yes (asking a learner)* *Learners: The water will decrease* *Teacher: Very good. Where is the other water? Where is the other water? Because we are having a glass or a bottle of water where do you think where is the other amount of water? Where is the other amount of water? Where is the other amount of water? Yes Nduksi?* *Once the water is more heated, the process- it evaporates. It disappears but because we scientist, we don't use the word the word "disappears" it evaporates then we come with process of evaporation. Once the water evaporates then the process of ….*	**Comment:** In this teaching segment the teacher is explaining the process of evaporation **In-depth Qualitative analysis:** **Teacher Amanda's Role:** The teacher asked learners what would happen when you increase temperatures and as you heat the water whether the amount of water will remain the same. **Learners' Role:** The learners responded that no the water will not be the same amount after 30 minutes of heating the water will decrease in amount **Teacher Amanda's Role:** Teacher Amanda further asked learners why the amount of water decreased and asked where would the other amount of water go **Learners' Role**: The learners did not know where the rest of the water would go

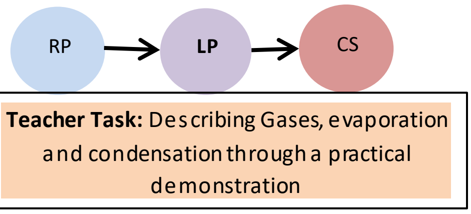
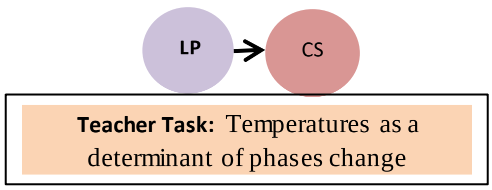
Learners: evaporation takes place. *Teacher: Once the water evaporates, once the water evaporates the process of evaporation takes place class?* *Learners: Once the water evaporates, the process of evaporation takes place.* *Teacher: Once the water evaporates (pause) the process of evaporation will takes place. Once the water evaporates the process of evaporation will takes place…….* *Ok my question was …..No it was a question- it is – I was still explaining –was it a question or I was explaining something? What was it? I explained ? Come again?* *Learners: About evaporation* *Teacher: About evaporation, ok I was saying during the exams you will asked what happened, what has happened and you can be asked what is the process – so you need to be able to tell what has happened.* *If you're saying "it freezes" but the process" freezing". There are two different meanings here. The other one is a process. If you are asked what process has happened, you are supposed to say freezing but if you are asked what has happened – the water has …?* *Learners: freezes* *Teacher: The water, but if it is the process? Sanukundigqibezelela, what is the process?* *Learners: The process is freezing but the water has freeze-* *Teacher: Then if you asked the water has?* *Learners: Freeze* *Teacher: But the process is?* *Learners: Freezing* *Teacher: Then we said pro matching- if you want to see the water vapor, the water evaporates but the process is evaporation that means in simple English the water disappears but because we scientist we use scientific terminologies. We use scientific terminologies. You cannot say in Science- it disappears, No it evaporates and the process is evaporation.*	**Teacher Amanda's Role:** The teacher then explained that once more heat was added to the water, the other amount would evaporate through the process called evaporation and told learners while they might think the rest of the amount of water disappears, in science learners were not allowed to say the water disappears but evaporates , the teacher further emphasis that distinction between a process and what happens to substances using the freezing process, that when referring to the process it becomes evaporation or freezing process but if in the assessment learners were asked what happened to the water, they must be able to say water evaporates or water freezes In the discussion above, the teacher is using LP/CS interactively to guide learners into understanding what evaporation process is. The resulting TSPCK Map for this TSPCK episode is given as follows: 
13-20 min: Describing Condensation Process *Ok before we go to the kitchen –once you boiled the water, if for instance you happened to be boiling the water next to the wall, that water vapor it goes to the wall. What do you see there? Somebody told me when I was starting this lesson when you're heating the water and boils and your water is next to the wall like this(showing using a hand) so that you can see clearly. What you see from the wall?* *Somebody told me! What do you see?* *Learner: Water vapor* *Teacher: Come again?* *Learner: You see water vapor* *Teacher: You see water vapor but once heated the, the, the wall it becomes? Somebody told me about the word starts with B?* *You see some bubbles. You see some bubbles and that means once that water vapor has come with another temperature again because the wall is cold; because it was boiling and you saw that there is water vapor coming out of the kettle or from the pot, you find water vapor but once it hits the wall, it changes and become what? And becomes what on the wall? Those bubbles will come back and become what? Yes, you will see what on the wall?* *Learner: They become water.* *Teacher: Very good, those bubbles when you're watching them you find that they become water again. Then is science we say the water vapor condenses, it condenses and the process is condensation.* *Teacher: The water vapor condenses class?* *Learners: The water condenses.* *Teacher: The water vapor condenses. Again!* *Learners: The water vapor condenses*	**Comment:** In this discussion, teacher Amanda is explaining condensation process. **In-depth Qualitative analysis:** **Teacher Amanda's Role:** The teacher started the discussion by asking learners what happens when you boil water next to a wall and specifically zoomed the focus of learners to what they observe when heating water next to the wall. **Learners' Role:** Learners responded that you will observe water vapour and bubbles **Teacher Amanda's Role:** The teacher then explains that the bubbles that the learners were referring to were called condensation process. The teacher explained that when condensation happens the water vapour condenses and go to liquid phase the teachers further adds that water was in gaseous phase and going back to liquid phase. The teacher further adds that when water reaches liquid phase it could change to solid phase when put in a freezer. The resulting TSPCK Map for the teaching episode captured through this discussion can be mapped as follows:

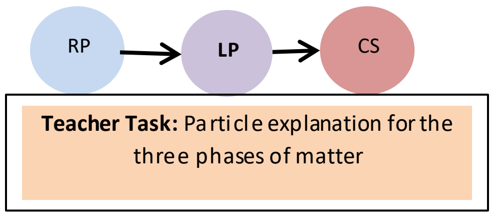
Teacher: And the process is called? *Leaners: Condensation* *Teacher: Masiyekini ushwantshwatha, the water vapor condenses and the process is condensation- that means the water is going to the liquid, can you see.* *Learners: Yes* *Teacher: It was gaseous stage from gaseous stage going back to liquid stage then you kept to the freezer and it goes back again to the solid stage. Can you see? Can you see that you will be having something like this? Can you see? Initially you were having water here (demonstrating), freezes (becomes ice) is it and once it is heated it melts. It melts and become water. Is it? Once it melts its water and once you heat it, it becomes water, it becomes water vapor but once that water vapor is hitting a cool place it condenses, the process is condensation. It goes back again to the liquid stage. It's like a wheel (making practical example) Can you see? Can you see? Can you please go and check if you can go to the kitchen so that we talk about something we have seen.*	
<u>20-24 min- Physical Processes of Phase change</u> *So, you must be able to tell me why, how can you make ice from water. How can you make ice from water, tell me? If you want to make ice from water, what can you do? If you wanted, if you want to make ice from water, what can you do? You change the water to the?* *Learners: Refrigerator* *Teacher: That refrigerator- in the refrigerator there is a part which is called?* *Learners: Freezer* *Teacher: Even here at school before we go to the kitchen I will show you the freezer and the refrigerator so that you can be able – because if you can just put the water in the refrigerator it won't freeze, you need to use that portion of the freezer or else if you got the freezer as we have here at school. It will freeze and the process will be freezing. That's how you can make ice* *And then if you want that ice to become water what do you do? What do you do? If you want to change that ice to become water what do you do? Oh ndititsha abantu abaleleyo shame. What do you do? Andisavuyi kuba yonke lento isesebhodini kodwa abanye abayazi noba bathini. Kukho abantu endingakhange ndizive kwa voices zabo. What do you do? If you want your ice to become water? What do you do? Yes Mark* *Learner: Not clear* *Teacher: and it will defrost. It will defrost. Once you have taken the ice from the freezer, once it's in another temperature because it was too cool there then once you take it for an example – this is an example there is no ice anymore. I am not telling you lies, there is no ice. I came here with the ice and you saw Mazandi. All my learners they must come back. Ok I am saying there is no need for you to heat the water if you want to change solid to the liquid once you change the temperature. All of them no ice anymore, I don't have any ice now, can you see? No ice, its water now, there is no ice, so if you want your ice to defrost you can take it away from the freezer, you take it to another temperature, the warmer temperature like in room like this classroom because the lights are on and some of the windows are closed so the temperature here it's a bit warm so it is affected that is why I've said there are variables which are needed to change the stages or phases of matter. There is no need for you to take a fire and boiled water if you/ I mean boiled the ice if you want to change and take any from the freezer. It will be affected by the temperatures of the room or even outside you can take an ordinary sourer/plate and you put and you put your ice, after some few minutes when you go and check, you won't find the ice because it will be affected by the temperatures to come to gaseous exchange I mean gaseous stage. I mean we said here once it defrost it becomes water and we said its melting. If the gaseous stage if*	**Comment:** In this teaching segment teacher is explaining to learners the conditions needed to change from solid phase to liquid phase **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** The teacher asked learners what must happen to become water (liquid) from ice (solid), **Learners' Role:** Learners responded that it must be taken into freezer **Teacher's Role:** The teacher then explained that the process is called freezing and confirmed that that is how you make ice. The teachers then asked what must learners do to change ice to become water again **Learners' Role:** Learners responded that it must defrost **Teacher Amanda' Role:** The teacher then further explained that temperatures were a variable which plays key role in changing ice to water. The teacher made an example using the ice she brought to the class at the beginning pf the lesson and told learners that the ice was no longer ice but water because the room temperatures were warmer than freezer and melting process . The teacher further added that even those temperatures were further increased the process of evaporation would start and mentioned that this would mean water has changed to gaseous phase and the process is evaporation. In the discussion above, teacher Amanda is using the knowledge of LP-CS to consolidate different phases of matter and physical processes which water undergoes into becoming different phases.

the temperatures are too hot and you take a saucer/plate, you put your ordinary water outside when the temperatures are 30 something/40. You just, you don't go for the fire. You've just put your water there and observe, you will find out that there is something coming out after some time if there is too much heat when you go and check the plate, its empty, the water has evaporates. Evaporation has taken place *Ok I think lets go to the kitchen before we go to the kitchen will go via the admin block to check the fridge and the refreezer so that all of them they must have a clear picture of what we are talking about*	
24-32 min: Temperatures a variable of refrigerator and freezer *Teacher: This is a refrigerator. This is what we call a refrigerator. This is what is called a refrigerator and this portion it's a freezer, when we talk of the freezer it's this part only. If you can put the water here it will freeze but if you're taking the water and put it here (bottom part of the refrigerator) it won't freeze that is what I was trying to explain to explain to you if you're taking the water and put it here even for a month your water wont freeze, but if you take your water and put it here in this portion (the freezer) your water will freeze immediately. Then let's go to the next room to see the freezer…….(Went to the next room)* *Teacher: Come two by two. This is a freezer. This is a freezer. This one is not a refrigerator, it's a freezer. If you put some water in here, the water freezes immediately. As I told you that the temperature they are the variables they determine what must happened to the water. Can you see? Come and have a look, this is a freezer. The ice I made you this morning, I've made it from this, come all of you. If you look at it –there is ice around it. Everybody must come. Everybody must come here and have a look. I think you Songo we're going to take this gas, we're going to use this gas. Everybody must come because when I am asking the questions, they will be based on this.* *We are going to class now. Let's go back to the class. Mazandi can you go to the kitchen and ask for matches quickly and a plate-enamel plate. Ok I think everybody now, as from today you can be able to differentiate when I am asking what a fridge is. It's not a fridge it's a refrigerator but we Africans we normally say it's a fridge. It's not a fridge there is nothing by this name fridge, it's a refrigerator. But most of the people they call it a fridge. It's not a fridge, it's a refrigerator.* *So you are able to differentiate a freezer and a refrigerator because this one immediately when you put something on it, it freezes but this one depends on where you have put your thing. Do you get me?* *Learners: Yes teacher* *Teacher: A refrigerator has got two portions. The other part is for freezing, the other one is for keeping things, not to be, not to be?* *Learner: Rotten* *Teacher: Rotten, for instance can you take, ok if you can have a slice of bread and you want to eat it tomorrow, where can you put it, in the refrigerator or freezer? If you've got an apple, you want to use it tomorrow; you have a freezer and refrigerator where can you put your apple?* *Learners: Refrigerator* *Teacher: Niyathanda ugqibezela kodwa – kufuneka ibenesiciko lev mbiza ungazingcolisi, ungazingcolisi, mayibe nesiciko le mbiza (sent a learner for a pot for experiment). If you want to keep your food not to have fungus or not to be spoilt you keep it in the refrigerator and if you want to keep it long- you put it in the freezer. And the freezer it is faster than the refrigerator. Even the top portion in the refrigerator it won't be effective as the freezer because of the temperatures; because of the temperatures, they both of them they've got places where they need to adjust them. If you want it to freeze faster, you can adjust it that means it is the variable,*	**Comment:** In the discussion above, there are no concepts of particle nature of matter involved except a lesson of what a refrigerator is and how different it is from freezer portion of the refrigerator. The teacher is explaining to learners that the temperatures determine what happens to water. The teacher then teaches learners about the correct term to use to what is popularly known as fridge and the difference between portions of refrigerator. There is little reference to how this affects particles of matter. The teaching segment could not be categorized into any TSPCK episode categories.

where you control the temperatures. Do you want it to be too hot or you want it cold.	
<u>33-39 min: Describing Practical Investigation</u> *You don't bring the gas in the classroom –we not supposed to be using gas, we supposed to be using science, science kit, like tripod. Can you see the fire? Can you see the fire?* *Learners: Yes* *Teacher: You can even lower the fire, can you see? can you see? So is why you can (put the pot on the burning cylinder) that is why I say it depends on the temperature, if your fire is too slow the water will take too much time but if your water, fire is too much it will boil faster. You have seen there is water here is it? And from the lid what is there? What is there (showing the lid to the class)* *Learners: Nothing* *Teacher: Come again?* *Learners: Nothing* *Teacher: Nothing, Ok (closing the pot) in science we're not supposed to use the gas bottles. We suppose to use the Benson burner. There was a scientist who was called Benson, who suggested that we can use the Benson- the burner and it was named after his name. Where is my piece of chalk? We're not for instance when we doing the investigation, can you tell me the stages quickly class? If we doing the investigation what stages must we consider, the first one, what is it? If we're doing practical task as we're doing it's a practical task. What must we have? Class talk* *Learners: Aim* *Teacher: Very good, one, the second one?* *Learners: Hypothesis* *Teacher: or?* *Learners: Prediction* *Teacher: After this hypothesis or prediction what must we have?* *Learners: Observation* *Teacher: and?* *Learners: Results* *Teacher: After this what must we have?* *Learners: Conclusion* *Teacher: We must conclude. But before having the Aim can we do a practical task without having things to use? What do we call things we going to use?* *Leaners: Apparatus* *Teacher: Or what?* *Leaners: Tools* *Teacher: So if you want to make an investigation or the practical work, when you say practical task, do you think you can see, you can see its practical, you're not theorizing, you're saying something you can be able to explain and state the reason why you decided to conclude like this. Do you get me?* *Ok my point was on the apparatus –we not supposed to use the pot, we not supposed to be using gas cylinder. We supposed to be using the Bunsen burner and are saying this burner it was discovered by a certain guy who was Bunsen. So it was named after his name, a certain scientist. A certain scientist, who was Bunsen, has seen that if we want to investigate things as learners in a classroom at school what must we do? We must have a burner, a small burner. It's not like and that burner was named after that scientist. Bunsen burner but because we don't have science kit but we cannot say we cannot do the experiments because of that you need to improvise-we need to think what can I use, what can I do because in order for you learners to understand and believe science you must always investigate, you must always do the practical, I told you that once before that if you want to be good, you must always do the practical work of it, for instance if you remember I said you cannot tell about the fungus up*	**Comment:** In this discussion the teacher is taking learners through components of a practical investigation such as the aim, purpose as well as equipment such as tripod, Bunsen. The teacher also told the learners about the importance of doing a practical investigation in science. The discussion does not contain any particulate nature of matter except the tradition of experiments within the field of sciences. There were no TSPCK episodes identified for particulate nature of matter.

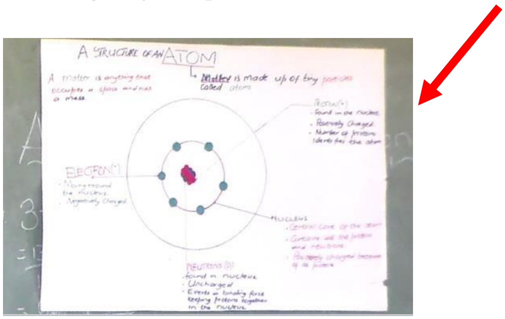
until you need to take the bread then wrap it and you observe what is happening and then you can tell me then, you will understand once you have done the practical or the experiment. It won't be easy for you to forgotten even if you go to Grade 12, you go to Grade 10 when the teacher is asking what are the phases of matter.	
<u>39 - 42 min: Experiment of Water Vapour to teach about Gaseous Phase</u> *Ok, let's watch there (boiling water) there is something. Ok what is it? What is it? There is something can't you see- can't you see there is something coming out from pot now? Come again? There is something which is coming out. If (khobaleke usifunele ifaydukhwe). There is something which is coming out from the pot that means the water- what is happening in the water inside? What is happening from the inside?* *Learners: Boiling* *Teachers: So what do you see here (around the boiling water) mmmh?* *Learners: Water vapor* *Teachers: Can you touch it and take it to me as I asked before?* *Learners: No* *Teacher: And after it has come out from the pot and goes to the classroom, can you differentiate that this is water vapor, no this is gas that was inside the classroom. Can you be able to differentiate now? Can you tell me that, no I can separate this water vapor from the gas which was inside the classroom? Can you be able to do that?* *Learners: No* *Teacher: No we can't, we can't that is why we say water vapor is dense, but when you look at it, you would think it's there, it's there, it's there, it's there but when you want to collect it you cant.* *Ok can you see this plate is dry, Can you see? Let us observe what will happen after sometime (put a plate over the steam) who can tell me what are your predictions, what do you think you will see after some time from this plate, it's already there. Tell me before I show you?* *Learners: Water vapor* *Teacher: Very good, can you see, have you seen that it was dry but now because it's cold it but if we have warmed this plate before you put it next to this water vapor, you were not going to be able to see this water vapor Can you see some drops of water but we said you cannot touch the water vapor but if the plate is dry- this plate is dry there is nothing here. Its dry but once you put it here (around the steam/ water vapor) . Ok another question, if I can leave this pot here and this gas (cylinder) on, tomorrow can I find the water in this pot?* *Learners: No* *Teacher: The process of evaporation will take place. The water will evaporate.Ok can you see now, what is it you see? Come again? What do you see now? What do you see? You can't see anything now? Can't you see, can't you see? What did you observe now? You can't see anything now? You can't, tell me what do you see? What do you see now? What do you see now? Tell me what do you see now from this plate class? Can you see? What do we see?* *Learners: Water vapor* *Teacher: We see water vapor but if I'm putting this plate next to this water vapor, we see some drops of water that is why I told you that the water vapor once it reaches a cool place it condenses. The process of condensation takes place that means it goes to liquid stage. It started from?* *Learners and Teacher: From the solid stage to the liquid stage, from the liquid stage to gaseous stage. From gaseous stage to liquid stage If we take this water to the freezer, it will? What will happen?* *Learners: It will freezes* *Teacher: It will freezes and get the solids*	**Comment:** In this discussion, the teacher is re-enforcing the concept of properties of gases using a practical demonstration of water vapour and uses this experiment to explain the gases. **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** As the water started boiling in front of learners (RP), teacher Amanda asked what was happening and what were the learners' observations **Learners' Role**: Learners responded that they saw water boiling and as the teacher asked what was happening around the boiling water then learners responded that they saw water vapour (LP) **Teacher Amanda's Role:** The teacher further asked if learners could touch water vapour. **Learners' Role:** No **Teacher Amanda's Role:** The teacher made reference to the fact that it was not possible to see, touch and distinguish between the water vapor and other gases which were surrounding the classroom, the teacher further explained that if they left the water boiling and come back to observe the following day, all boiling water would change into gas through evaporation process. The teacher further added that if that same water vapour made contact with a cold surface (lower temperatures) the water vapour would change back to liquid phase and the process was called condensation. The teacher then consolidated the session emphasizing all possible processes of change of state as she stated that from Solid phase Liquid stage→ Gaseous Stage →Liquid Stage → Solid Stage In the teaching segment above, teacher Amanda is using RP-LP-CS interactively to re-enforce the concepts around gases using a practical demonstration. The resulting TSPCK Map for this episode is given below:

	
42-46 min: Temperatures as a determinant variable for Phase Change *Teacher: Mbasa come back again- take this (pot) we are done with experiment, put it there. Just put it there and sit down. I want you to ask me some questions; I want you to ask me some questions. Do you believe that matter has got three stages or 3 states or 3 phases? Do you believe that?* *Learners: Yes* *Teacher: Why do you believe that? Why?* *Learner: We have seen it* *Teacher: Very good tell them, we have seen it. We're not theorizing it. When we see, not something we did not see, we have seen everything. We've seen the ice can you check what is outside this tube……what is outside?* *Leaners:* *Teacher: Yes because it was next to the heat that is why I said variables are very much important they can change the stage of the matter as from today we really believe and understand that matter has got three phases or three states or three stages. These are names it can be asked as phases, it can be asked as states and it can be asked as stages. But if you want to explain it you must always come up with an example and I've said the most/ the easiest way of giving an example of it is the water because water is a natural resource, we not going to buy water, I didn't buy this water. As a scientist we know we believe in things we have seen in our daily life, so the water is the natural resource and if you coming to the other, when you are doing Grade 10 what they make example of water, they will use the other elements of which they will be a little bit difficult for you but since you will be having these basics of that the water has got three stages and the good example for your standard is water. There are so many things you can use to see the stages of matter but this is the basic one for Grade 8s.*	**Comment:** In this discussion, the teacher is again emphasizing the importance of conducting practical investigation/experiments as a norm in science to believe/evidence scientific theories. **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** The teacher asked if learners believed that matter has three phase and why did they believe so **Learner's Role:** Learners responded that they believed that matter has three phases because they have seen it (demonstration) **Teacher Amanda's Role:** The teacher then confirmed the knowledge of learners and further stated that the lesson was not only based on theory but concepts of phases of matter were also proved through a practical investigation. The teacher added that as learners would progress into grades above Grade 8, they were going to learn about other examples of matter and their phases beyond just water and therefore emphasizing the increasing complexity of the topic beyond the grade she was teaching (CS). The teacher explained to learners that water was a standard example relevant for Grade 8 to give them basic knowledge about phases of matter In the discussion above, the teacher is using LP-CS to explain that temperatures determine the phase change 
46-51min: Particle Explanation for different Phases of Matter *Once you have seen this one, when you're coming and don't forget that I told you that if you're talking about the ice, I said the particles are closely packed for instance one of the question papers you are having 3 beakers. First one with particles closely packed to each other, the second one B with a shade in the middle, C with?*	**Comment:** In this section, the teacher is using an exam question to teach learners how the concepts covered during the lessons might be assessed during examination. **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda Role:** The teacher told learners that they should not forget that in ice (solid) the particles are closely

 *From these three beakers who can tell me which is the solid stage? I have three beakers, beaker A, beaker B and beaker C. The work is straight forward. Which beaker is having a solid stage? Yes Pinky?* *Learner: Beaker B* *Teacher: Very good B is having a solid stage, class?* *Learners: B is having a solid stage.* *Teacher: B is having a solid stage, class?* *Learners: B is having a solid stage.* *Teacher: Again?* *Learner: B is having a solid stage.* *Teacher: By mere fact of just having a look, you can see that it's closely packed. Which one is a liquid stage? Yes Liquid, Liquid? Njikelana* *Learner: A* *Teacher: A is a liquid stage, at least there are spaces and the last there are big spaces in-between. So this one (the one of the solid) it's the gaseous stage. So you cannot be asked in a same way but this is a sure question. Water and material you will be given the three beakers then to identify. Ok if we're talking about this one we said it's a solid stage that means it's a? What process is happening here? What process is taking place here? Freezing is taking place class?* *Learners: Freezing is taking place* *Teacher: This one (beaker A, the liquid stage)?* *Learners: Melting process* *Teacher: Come again, andiva?* *Learners: Melting process* *Teacher: Ama-boys kumnyama ingathi bekutitshwa engekho ethathwe ayobekwa phandle. What process is taking place here?* *Learners: Melting is taking place.* *Teacher: This one (beaker C, beaker with particles with spaces)* *Learners: mumbling* *Teacher: Come again?* *Learners: mumbling* *Teachers: Come again, No if we saying this one is freezing (beaker B) then we saying this one (beaker C) is melting, the third one is? Then once it's boiling, what process is taking place? The water evaporates and the process is evaporation. It goes back to the process of condensation and it becomes water vapor.*	packed and then made an example that in one question paper there were three representations of beakers labelled A,B and C with the first beaker had closely packed particles and beaker B was just shaded and beaker C. The teacher then asked which beaker was a representation of solid phase. **Learner's Role:** A learner responded that beaker B was solid phase **Teacher Amanda Role:** The teacher confirmed that Beaker B was solid phase, beaker A liquid and beaker C gaseous phase. The teacher explained that glass A was liquid because there were at least spaces between the particles and glass beaker C was gas because there were bigger spaces between the particles. The teacher further added respective physical processes for each beaker as she stated that for beaker B, freezing process takes place, for beaker A melting process takes place and for beaker C evaporation takes place. In the discussion above, the teacher is using her knowledge of assessment to introduce learners to particle explanations behind each of the three phases of matter. The teacher is therefore using RP-LP-CS to explain the difference between liquids and gases. The resulting TSPCK Map for this episode is given as below: 
51-56: Measurements *Any questions? So far so good? Ok can you tell me what the density is? When we are mentioning the word density? So dense! What do we mean when we're saying density it's because of the density? What do we mean? Ok another question. Water is measured in what? What are the measurements/ units of water? If we talking about liquids. Liquids are measured in? Liquids are measured in? In? Come again? Ok let's start with when the ice is freezing, we talk of? We talk of? We talk of what? We talk of?* *Learners: Freezing*	**Comment:** In this teaching segment, the teacher is explaining to learners the measurements for temperatures, liquids and solids. **In-depth Qualitative analysis:** **Teacher Amanda's Role:** The teacher explains to learners about measurements of liquid water are given in milliliters or liters while the solids are measured in grams or kilograms. The

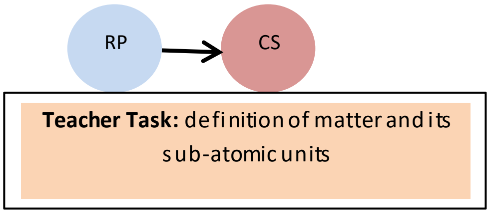
Teacher: No don't start here (freezing) start here (degrees Celsius) class? *Learners: Degrees Celsius.* *Teacher: Degrees Celsius, once it freezes that means it tells that the temperatures, so the temperatures are measured in degrees Celsius. Then you talk about water. The water is measured? What are the measuring units of water, of liquids? Even if it's not water, talking about when was I teaching you? I was not teaching you…..? You were taught by mw but you were not taught by me in Mathematics. Let's talk about mathematics unfortunately you done in mathematics. All those who were at school here even if you were schooling somewhere, you cannot come to Grade 8 without measure. If were talking about measure, I told you that when we talking about teaching we talking about integration. Even if I am teaching you science, mathematics is there. Ok when we are talking about measurement, if you measure the liquid you measure that is standard unit of the measuring unit for instance, I used to tell you that draw some? I used to ask you, you draw some 2 liters of water so they are measured in liters and milliliters, it's a simple question. Ni-lost ngoku kuba kaloku sithetha nge-Science i- measuring iyohlala iyi- measuring ikhona ke nalapha kwi-phases of matter. Nje ngokuba uyilibele nje, once uthethe nge mass, once you saying matter is anything that occupies space and has a mass or weight siyigqibile uthetha nge measurement yethu. So you must always know that water is the standard units for measuring water, they are liters and milliliters siyevana, once you talk about ice. They are measured in because they are solids in grams and kilograms siyevana?* *Learners: Yes* *Teacher: Any question? I think now they are tired now. Are we not done? Ok let me give a chance to….. #end*	teacher added that temperatures were measured in degrees Celsius. This teaching segment contained no TSPCK episodes as the teacher was explaining to learners measurements of materials.

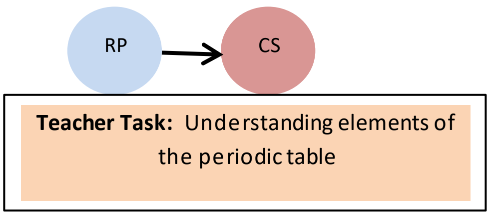
APPENDIX 15: Analysis of teacher Sophie's enacted pre-intervention lesson

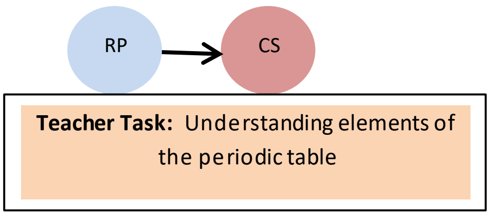
Lesson 1	Comments / Qualitative In-depth Analysis
<u>0-2 min</u> Teacher: We are going to learn about an "Atom" you still remember saying to you, you must draw your own periodic table? Learners: Yes teacher Teacher: And then you did it? Now before we deal with the periodic table, we must start first introduce the word "atom". Someone will query or will have a question or cons entity of what is an atom. Now I tried to give you a picture of what an atom is.  Now I think from the previous class you know what the name matter is! What is it? If you are aware of that name- A matter-, it is anything that occupies the space and has a mass or it have a volume. For example this desk that you are seating on, it occupies this class and it has a mass and it has a volume. So this desk we can refer to as a matter. Now take another example as we were dealing with living life and living, we were dealing about flowers, we were dealing about plants and their biodiversity , the biosphere. Now if you can take for an example of the soil, the soil occupies or let's says the grass, the grass occupies a certain part of the soil due, are you familiar with it? And that grass has a mass and it occupies and we call it a matter are we all together? Learners: Yes teacher	**<u>Comment:</u>** In this discussion the focus was introducing atom **<u>In-depth Qualitative analysis:</u>** **Teacher Sophie's Action :** Teacher Sophie had brought a diagram of an atom and told the lerners that they were going to learn about an atom and immediately reminded them that she once requested them to draw periodic table but needed to start with atom before periodic table **Learners' Role:** Acknowledged the claims by teacher Sophie as they all sange "Yes Miss" **Teacher Sophie's role:** Teacher continued to remind learners that they should have learn the name "matter" from precious grade, the teacher then defines matter for her learners and states examples of matter such as desk. The teacher has introduced three concepts atom, periodic table and matter without making any links to how each informs the other, there were no other concepts introduced to learners except definition of matter and therefore in this discussion teacher Sophie is using curricular saliency to define matter in isolation to any other TSPCK component thus No TSPCK episode in this teaching segment
<u>02-04min</u> Teacher: Now then we come to a definition; we have defined what a matter is. Now an atom is from the definition of a matter. Now we said an atom, then we said a matter is made up of tiny particles. Now if you can take a soil and you touch it, you feel it, what will happen? What will you experience? .You will experience small stones neh? Learners : yes teacher. Teacher: This one, you can say that small particles that make a soil. Small tiny particles make a soil. So now that matter is made of tiny particles it is called an atom. Now this desk is made up of, you see colours. This colour if you can see are pattern to one another, one another and these are tiny particles and they form this desk. Now let's say this book, it is nice, it is covered siyayibona mos neh? Learners: Yes teacher Teacher: Now this book before this cover starts it was a picture and now then this picture when you take your phone or camera and make a photo shot and when you go and make a photo now what will they do? In older days they will put something that is blackish in colour, they will put it in water and then it will start to make pictures that one will call tiny particles that make a picture. If a cellphone we call it a mixer and that are the tiny particles that make a picture siyayibona? Then when your picture is about ukuvela apha ephone-in yakho what	**<u>Comment:</u>** In this discussion the focus was on the definition of an atom **<u>In-depth Qualitative analysis:</u>** **Teacher Sophie's Action :** the teacher told learners the definition of an atom which was immediately accompanied by some confusing examples **Learners' Role:** None except for resonding with Yes in everything that the teacher claims **Teacher Sophie's role:** The teacher gave learners definition of an atom and linked this to matter as made up of tiny particles called atoms. Teacher Sophie is again using curricular saliency to define atom in isolation to any other TSPCK component thus No TSPCK episode in this teaching segment

will happen? It will start to flicker, flicker, flicker until it make an image of you.	
<u>04-07 min</u> Now if we talk of an atom this is, we call an orbit siyevana moss. This is a now you remember in N.S we talked about the nucleus now the nucleus we said the, it is the center where the, anything has happened that means the cell it is happening in the nucleus. Now we still have the nucleus it is very important. Now when we look at this circle of ours it has a dot. I tried to make the colors so that you can see the difference. Now let me make this example; do you see this?(showing the geography globe with continents) Learners: Yes teacher Teacher: It is round, it is like a nucleus, it moves. You see? Now we'll take this circle as this one at the circle there is a nucleus siyayibona moos neh. There is the center in the map we call it the equator that divide this one and that one moos neh? Let's take that equator as our nucleus. Now if you could see this one, you can see that matter makes an atom. It is divided into three; it can be a solid, a solid, a solid. This is a solid you see, this a solid and this is also a solid. Now it can be made as a liquid this is water.	**<u>Comment:</u>** In this discussion the focus was on the definition of an atom **<u>In-depth Qualitative analysis:</u>** **Teacher Sophie's Action:** The teacher then refers to the chart of Atom which she brought to the class as an orbit then starts labelling the sub-atomic units of an atom. Again the examples that are used can be very confusing the definition of an atom which was immediately accompanied by some confusing examples. **Learners' Role:** None except for resonding with Yes in everything that the teacher claims **Teacher Sophie's role:** The teacher then explained that the globe was round and moves like nucleu of the atom, the teacher further explained that the equator of the globe is like nucleus as they are both at the centre The teacher analogies of a nucleus were rather confusing and this discussion had No TSPCK episode
<u>7-9 min</u> this is water you see? This is water moos neh? It is in a form of a liquid. Now it can be in a form of gas. Now we said when we define gas or an we said it is around us now then there is easy example to be presented, yes we know there are many gases that are in around the class but if now I blow or breath out-that is coming outside so now I said we have a gas, we have a solid and then we have a liquid as water not all liquids is water, they can take the colour of the water but they are not water taken an example of paraffin. It is a liquid but it is the same as water, but when you smell it, it is totally different. When you look at its mass it will be totally different. Now these are the examples of matter, you can we measure the matters that is the fruit. Now then what can we say? Another thing we cannot see the gas that means gas we cannot see with our eyes but it can be collected. This is a balloon, what they do to this balloon? They blew it, they know inside the is a gas.	No TSPCK
<u>9 – 11min</u> Now you can see this ruler, it is in which form? Learners: Solid Teacher : It is a solid nhe! There are examples of solids. These ones are solids, these ones you can put liquid inside, you can also put the solid inside, you can also put the sans inside siyayibona mos neh? Leaners: yes Teacher: Now this ah- this is a ruler, sand the, then now this is liquid, you see ……………is a Benson burner and the is a glass-we call it a ……in NS. Now we can put a liquid, you can also put a solid. But most of the time we can put liquid inside this …… Now let's come to this Atom, when we define an atom. Now when you want a complete atom. It must have this- this is a lanto – we said a matter is made of small particles which are called atoms. Now these ones we call them electrons- these are changes/charges siyavana neh. …………………the charges are divided into two, the negatives and the positives. The negative charges we call them electrons- uyabona moss neh!	No TSPCK

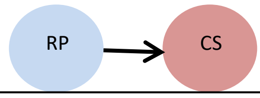
Learners: yes Teacher: They are, they are outside the nucleus - they are moving, you see- ……….orbiting around the nucleus. They do not come to the nucleus. Now we have another type of charge which is protons, which is positively charged- now it is inside the nucleus. do you all see? Kids: yes Teacher: These are the green ones.	
11-13 min Now let's look what will happen with what are the blue ones. These are the neutrons that means now they are uncharged, you cannot say they are positive or they are negative or if the number of these protons and electrons are the same we call them the neutrons. That is why we call them zero because they can't charge negative, they cannot charge positive. Now what will happen is that, these neutrons, protons we call them protons let's define them. They are found inside the nucleus. That means inside the nucleus. You cannot find them lying there, you cannot find them lying outside the nucleus, but they are inside the nucleus. What else do we know about protons? They are positive charge. Then- now the number of proton identify the atoms, the number of your years identify you Asemahle, you cannot say Asemahle is 5 years old whereas Asemahle is this tall(using a hand sizing a tall person)) Now when you say Asemahle is 5 years and then come in Asemahle then Asemahle is this (tall) wouldn't you be surprised? Learners: You will be surprise Teacher: Now if you identify your years, identify, actually identifies you not unless the is a problem with your growth then you can say this is Anathi, even maybe a 15 years old is like this (short) you will be surprised how come that person is that short.	No TSPCK
13-15 min We come to the nucleus. What can we know about the nucleus, it is the central core of the atom, contains all the protons and the- we say this is the nucleus-what is there in the neutron- it is only the protons and the neutrons. Then how is it- it is positively charged because of it protons. Now remember the protons you said are positively charged. So your nucleus will be positively charged because the neutron does not have any charge, they are uncharged now kuthwa it is also found in the nucleus, it is uncharged. It exerts a binding… keeping protons together in the nucleus. Now you see the protons, where are the protons-the red ones are held together uyabona moss neh, are attached to one another it's because of ilantuka (pointing at the sentence that says: it exerts) and then now the protons are attached together, it makes the protons not to split, now let's come to the electrons. They are moving around the nucleus, they are rotating, they are rotating as this one (demonstrating), they are rotating, they are rotating like like this (using ….), they do not go, they do not go, to the nucleus, they are moving, they are moving around the nucleus, they do not go inside the nucleus, they are moving around nucleus and they are negatively charged. Now when the atoms are charged, what will happen? Now we know positive combo and negative there will be attraction.	**Comment:** In this discussion the teacher is using the chart which represents an Atom to teach learners the different sub-atomic units of an atom I**n-depth Qualitative analysis:** **Teacher Sophie's Action**: Teacher Sophie is using the chart she has drawn which represents atom and its sub-atomic units that are "protons, neutrons, electrons and nucleus with their respective definitions to explain to learners what an atom is. At this point Teacher Sophie further uses a textbook diagram to label the atom at a sub-microscopic level. In the discussion above, teacher Sophie is drawing from her knowledge of representations (REP) to explain the structure of an atom and her explanations are drawn from her knowledge of curricular saliency (CS). Firstly, after putting these two models, teacher Sophie used them to explain the sub-atomic particles of an atom. The teacher is therefore using RP-CS to

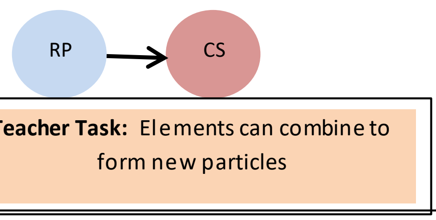
	explain atom and its sub-atomic units. The resulting TSPCK Map for this episode is given as below: 
15-17min For an example you use this thing in your home- everyday life, you have this all ……… , ……… you see it has positive as well as negative, now I order for them to charge you need at least 2 hormone. Then you will put positive (that T) that is on at the top, there is something that is taking out you can see moos neh? It is positive and then beneath it is negative. Now you need to put this part that to the second one, you take this part on top (vice versa on two small cells/ batteries). So they will be charging, they will be moving now the electrons will be moving, proton now become to- they will go. They will be attracted by the, the? Learners: Electrons Teacher: We said the electrons, they don't come to the nucleus but they go around. Now siyayibona moos neh! They are moving around and then now when it is changed it is only the proton that will go to the electron andithi? In life situation, when you see a boy we have dealt kwi human reproduction system andithi?and now when uYamkela goes there to Asemahle to check , Yamkela goes to check. Now we take female as negative and the male as the positive. Now the male will go to the? Learners: Female Teacher: Not female will go to the? Learners: Male Teacher: A male is supposed to go to the female, male is a proton and a female is an electron so you male must go here (to the electron) not you female come here (to the proton) there will be a problem. A female coming to you will be ashamed of your situation, " Ahh how can Asemahle do that " but if Yamkela goes there that's normal. We see that it is all about the atoms.	No TSPCK Episode
17-20 min Now if we you take a piece of chalk , you see a chalk moos neh, If you take a piece of chalk and you start to chop it until it is fine okanye until you can never cut it into pieces that one. It means that there is tiny particles- that one we call it an atom because an atom is indivisible. You can't divide it anymore siyayibona moss! That's why now ke we can say this water- can you cut water? Learners: No Teacher: No we cannot cut water and the solids you can cut out this there will be a one point where you cannot cut it anymore. You can make this one- you can tear this book into pieces but there will be a piece that cannot be tear, it means it is that tiny particles. Any question? Any question? Kids No Teacher: Ok this is a nice picture about the atoms. This is the nice picture you can all see. You see this one, they means they are orbiting around the nucleus. This is a picture, a nice picture. You can, this is a picture now we will proceed to the periodic table. We will proceed to the periodic table. You can take out your, your books.	No TSPCK Episode

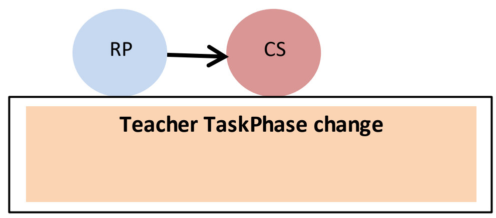
Now in the periodic table as you draw you have notice that there is different types of elements. An element that is no 1 is different is not the same as in the elements in No 2 as well as element in no 2 is not the same as the element in no 3. Now if your periodic table –where is my periodic table (looking for it in her desk). This is my periodic; you/ those who also like nice handwriting, nice colors but you can see those are the different…... Element 1 up to element bani? Learners : Element 20	
<u>20 - 23 min</u> Teacher: That means the first 20. Now you see this element is made up of tiny particles siyayibona moss neh? Element that is in one it is made of tiny particles that are not the same in element two. There is the difference. Now this periodic table as they denote in colours, its either they are **Solid, Liquid** or they are in a form of **Gas** (demonstrating using a cup of water, and a plastic that is filled with air/ balloon) siyayibona moos neh? Learners : Yes teacher Teacher: That's why they are making them in a there. This one you see they are the same colours. This one they are the same colours and you see if they are purple, they denote something. Now I was trying to show you that even the periodic table is arranged in order so that element no 1 has its own tiny particles called that are atoms , element no 20 has its own particles that are not the same. Now even if you see we have the columns and we have the rows. You see this one are go down (element 1, element 2, and there are these (horizontal ones). Those who are going down we call them the group's siyayibona? These ones we group them. Now it's like in the class, I group you according to your performances, something similar. If I want those who are less than 10, you remember what I did moos neh, we were writing an experiment. I said those who are less than 10 must come here, those who do not; I was trying to group you according to your performance. Now they are grouped according to their similarities because they are not the same but they are similar. They are unique and then now this one we call them the periods, the rows-they are the periods. Now this is, they take out an element that is **Mg.** Where do you see **Mg**, in column 1, column 2, column 3 or column 4? Magnesium**, Mg** where is it in your periodic table? Kids: No 12 Teacher: Which column kaloku ? Learners: Group 2 Teacher: They are in column 2 which is group 2 moos neh.	**<u>Comment:</u>** In this discussion the focus of the lesson was on the first 20 elements of the periodic table **<u>In-depth Qualitative analysis:</u>** **Teacher Sophie's Action**: Teacher Sophie is using periodic table to teach learners key cocept of the periodic table such as element and how elements are grouped in the periodic table while using symbolic representatins such as Mg to make examples of how elements are grouped in a periodic table In the discussion above, teacher Sophie is drawing from her knowledge of representations (REP) to explain elements of the periodic table and is using symbolic represantations that means she is also using her knowledge of curricular saliency (CS). The resulting TSPCK Map for this episode is given as below: 
<u>23 - 25 min</u> They take out, when you take out an Magnesium, now when you see 12 above andithi and 2,4 below? And in the middle you will see ee abbreviation **Mg** moos neh? Take care first letter is capital letter and second letter it is a small letter. It will be like that in all elements in the periodic table. The first one it is the capital letter and the second one it is a small letter. Now what else we do? The above letter we call it an atomic number. Does it ring a bell when I say atomic number? Number of atoms, how many atoms that make **Mg,** that means the number above there it will tell you about the atomic number and the number that is downwards it is called mass number or called atomic mass. You remember when you define the matter, it is anything that occupies a space and it has a mass that atomic number will tell us. Atomic, when we define atom kuthwa a matter is made up of tiny particles that called atoms. Now in order to count me Magnesium, there were tiny particles that made Magnesium and it won't be the same number as **Be** which is Berelium, it won't be the same as **Ca** which is a Calcium	**<u>Comment:</u>** In this discussion teacher Sophie is using an example of Magnesium to teach students key aspects of particulate nature of matter in the periodic table such Atomic Number of an element. **<u>In-depth Qualitative analysis:</u>** **Teacher Sophie's Action**: Teacher Sophie is again using periodic table to teach learners cocepts such as atomic number and symbolic representations which are used in sciences to represent elements. The teacher links back the concept of atomic number of elements to her ealier definition of elements being made up of tiny particles called atoms. teacher Sophie proceeds with her lesson to teach her

	learners that these single atoms build up bond to together to form giant atoms that are called elements and teacher brings the concept of periodic table to the learners. Teacher Sophie used the periodic table to expose her learners to different types of elements which are made up by different kinds of atoms. Teacher Sophie focused the lesson on concepts such as ways of reading the periodic table such as reading atomic number: In the discussion above, teacher Sophie is drawing from her knowledge of representations (REP) to give meaning to atomic number and atomic number is unique for each element. The teacher is also drawing from her knowledge of (CS) to explain concepts. The resulting TSPCK Map for this episode is given as below: 
<u>25 - 28 min</u> because the number of atoms are not the same, the atom they are unique as people fingerprints. Siyevana You can not say it can be similar as they are in group 2 they are similar they have the similarities but they are not the same Asemahle you can be similar to Amanda but you are not Amanda. You are from the same parents but when we take your fingerprint, we cannot say Amanda take my fingerprint, put there, and go with them to the police station that means you need to cut your fingerprint to go to the police station. There is no one who can fake your fingerprint. Even the elements is, is they are unique as that as our fingerprint. If you want my fingerprint, you have to cut this one and go with it but if I am still alive, it's only me who can be able to go and say I did this, I need my fingerprint for this, you see now? No one can take out your fingerprint the atoms it's like that. Any question? Learners: No teacher Teacher: Now if the access of the lantsika, now we need to be familiar we said we breathe in, ok we breathe in we have Co2 – C must be capital and O must be small letter. We have Co2 that we breathe out andithi? We have Carbon dioxide that we breathe out. Now Co2 will notice that it is made up of two elements C and O- C for Carbon and O for Oxygen siyayibona moos neh? (learners - answer yes) How many atom that makes of C (Carbon) that makes Carborn dioxide? One sibona ngo C abangaphi? Learners: One Teacher: That it means one atom. How many for ilantuka iOxygen?	No TSPCK Episode

(leaners answer-one) We also count its either it will be down one, we count even this one(referring to O2) We said Oxygen will have two (2)atoms,	
<u>28:31min</u> Carbon will have 1 atom because there is one here(C for CO2) and there is two (O2) siyayibona moos neh? (Learners answer yes teacher). If now you take water for example let's take water- Water its H2O and here we said (CO2 – I atom of C and 2 atoms of oxygen). The reason I write Oxygen in full because if I write O you can easily confuse to say its zero that's why I write oxygen in full. Now how many atoms of hydrogen in water? How many atoms? Huh? Learners: Two (2) Teacher: Two neh?(learners answer yes), very good H2O (two atoms of H & 1 atom of O). Remember English your first and how many atoms. English must be brought, two atom**(s**) neh and one atom (learners answer with yes). Don't say one atoms because there is one you see that's why ndisithi your English must be brought. Now tell us, now hydrogen. Now you see they were two here (Co2) now they change to be one H2O it means it is not the same thing, oxygen that makes (Co2) will not be the same , it is the oxygen but it does not have the same atoms. Now here H2O we have one (1) atom and there (Co2) we had two atoms, you see? Learners: Yes teacher Teacher: Ya it is like that, hope we understand. Now if you combine two or more atoms it is called a…………………..# knock at the door!!!	NO TSPCK Episode
<u>31-33 min</u> Now I was still saying that if you take these elements it can be oxygen but it cannot work the same as ulantuka as it works for ubani? Co2 and H2 O then you take it and compare this oxygen that, they don't work the same here its **water** (H2O) it will not work the same as in Carbon dioxide. What is the remedy there? Your periodic table it's not just any, it is arranged in order. They move from left to right for you it will on from right to left, for me it will be from right to left neh? They move from this direction to this direction and from upward to – downward. Now let's see that one, you see the first one is hydrogen neh it has H- one neh!You stick to that one, lets take any eee then we said hydrogen and Na its sodium neh? They are in the same group but they don't have the same number of atoms siyayibona moos neh? Now you see it is why it- what nk there……. the number that is above? Learners: 11 Teacher: 11, now you see the other one is 1 and the other one is 11 kodwa kuthwa base groupin eyi one? Andithi nani nibe kwi group eyi one ningen 'aminyaka ilinganayo moos neh okanye iperfomance yenu ingalingani niyayibona? (learners respond- yes teacher) that is the same	**<u>Comment:</u>** In this discussion the focus is on how different elements can combine to form new particles **I<u>n-depth Qualitative analysis:</u>** **Teacher Sophie's Action** The teacher used examples of matter which learners were familiar with such as water and carbon dioxide and shown them that each were made up of a combination pf different elements from the periodic table. . In the discussion above, teacher Sophie is using her knowledge of representations **(REP)** including analogies interactively with knowledge of curricular saliency **(CS)** to explain how matter is made up of tiny particles that are called atoms. Teacher Sophie continues to show her learners that different elements can 'combine' to form newly and unique molecules which are different from their respective 'reactant' elements and emphasizes the symbolic representations **(REP)** when teaching this concept: The resulting TSPCK Map for this episode is given as below:

	 **Teacher Task:** Elements can combine to form new particles
<u>33- 35 min</u> Now it tells you that hydrogen there is no way- let me say if you have R1 and I have 10cents who, who must come to one? Who must- you have , Asemahle have R1 and I have 10c we want something to eat , Asemahle is now in short of 10c and I have 10c, what will happen? Who will have more input or who will have more say ? Asemahle who say I have R1 and I am short of 10c give me your 10c? Would you mind if I say Asemahle I have 10c please give me your R1? Learners: yhuu No Teacher: You see. You see? Now it means mna I must come Asemahle here a 10c you are in short of 10c can we make a combination so then will get a quarter of bread and will eat. Now when we get that the quarter, will Asemahle says you give 10c so I will give you something that is equal to 10c or do you share equal? We share andithi? (learners answer-yes) That is what we do. Even the elements they do that even the one that in shortage will come. Hai let me come to you so that we can combine to form water. Now what will happen, they will share equally. H won't say I had small and oxygen say no wena you were mancane (learners: laugh) You see it will say " no we will make a good combination at the end will have to be friends because we have shared something siyayibona moos neh?	No TSPCK Episode
<u>Lesson 2</u>	
<u>0-2 min</u> Let's look at hydrogen and let's look at oxygen now. Let's look at hydrogen, where is it? It's up there neh! Learners: Yes Teacher: And the number of atom, how many are they?One neh! ;Look at oxygen how many are they? Number of atoms Learners: 8 Teacher: Which one has more atoms 9 (learner's answer-oxygen) now preferable hydrogen will go to oxygen, not oxygen. We said they move from this side to that side moos neh, that means hydrogen those which we are in this side will go to the other not this one will go to the other side that's how they work. Now let's take water, water as a liquid remember not everything that is a liquid is water neh? Now take an example of a liquid as water. Now a water undergo that stages we said it is solid, it is liquid and it is also a gas (someone at the door) Grade 8 you can…….	No TSPCK Episode
<u>2- 3 min</u> Teacher: Now I was saying apha atoms that apha Co2 there is only one Carbon atom and O2 (two Oxygen atom) and then let's see the combination of H2O and Oxygen gives us water. They have two hydrogen atoms as well as one atom of oxygen. Now the combination of the two or more atoms we call them the molecules that means ke ngoku how many atoms do we have? We have two (H2) and one (O)	No TSPCK Episode

and then a definition of a molecule we said it is combination of two or more atom. We said hydrogen the hydrogen there is one for water. There is one hydrogen atom and two oxygen, there is two hydrogen atoms and one oxygen atom, that means i-atom if we can count one, one, there are two for hydrogen. Andithi there is one that means it covers this one (two or more atoms) they are two or more atoms. They give us a molecule, now it means that for ulantuka, water will say it is water molecule because it consists of two or more atom. It consists of two or more atoms. It consist of two or more, you can say it consist of three atoms. If you calculate Oxygen (O2) to be two and Carbon to be one then they give you then 2+1 which will give you three and it comes to two or more atoms.	
3 - 6 min Now we have now a particle model of a matter. Now to… We are going to use water; we are going to use water. Why water? Water can undergo three stages, which is Solid, Liquid and Gas. Now let's come from this one we said water it is made up of ubani [a xhosa word meaning what]? Hydrogen and Oxygen. Then they give us the arrow which means the result now- they give us water. Now hydrogen and Oxygen you see that they are starting up to making what is on the right hand side andithi [a xhosa word meaning "right?]? Now all the substances that start up the reaction we call them reactants. These two ($2H_2$ O_2) they start up the reaction. Now we call them reactants. Now after the reactants have combined, they will give you a product siyevana moos neh? Now when you combine you have, you, you want to make a tea, you must have a sugar, you must have a tea or coffee and you must have boiling water. These are your reactants, ok when you combine sugar, tea, boiling water, they will make a same combination. You cannot take out the sugar andithi? It will be black in colour andithi moss neh? You cannot take out sugar there after you have made that solution. You cannot take tea out.You cannot take water out moos neh? They are now combined then last stage when a tea, sugar and a water boiling water they combine we call it a reaction but water, sugar and a tea are called reactants. Siyevana mos nhe	**Comment:** In this discussion the focus is on how different elements combine to form new products [compunds and molecules], the teacher is talking to foundations of chemical reactions **In-depth Qualitative analysis:** **Teacher Sophie's Action**: Teacher Sophie stated that the learners were going learn about particle model of matter and stated that in learning so they were going to use water. Teacher Sophie then immediately jumped into chemical reactions as she directed the discusiion into how water forms using the different elements of the periodic table showing learners how different the water molecule forms as a result of a reaction between Hydrogen and Oxygen. Thi sdiscusiion is facilitated through use of periodic table and symbolic representations of elements and molecules. In the discussion above, teacher Sophie is using her knowledge of representations **(REP)** specifically symbolic representations to teach learners how molecules form from elements of the periodic table. These representations are used to explain concepts of chemical reactions to form molecules which is an indication that teacher Sophie is drawing from her knowledge of curricular saliency **(CS)** to explain The resulting TSPCK Map for this episode is given as below: 

<u>6 - 8 min</u> If you are going to cook a rice, you need something that will make a, you need a pot andithi? You need rice as the ingredients as the rice, you need a salt, you need water, you need even a stove or anything that make your rice to cook andithi? Learners: Yes Teacher: All these we call them reactants. You can't eat rice when it is raw. It is dry and it is not/ you can't even bite then you feel it when you bite it. But after you have cooked it, you can be able to eat it without that you can try hard to eat it. Now that we call it or these we made with rice we call you call the reactants. The result it is the product of ilantuka, the , you cannot say after you have your rice, you say I can see the salt, I can see the water, I can see the… Yes you can see the riceeven the colour has changed white. Then when it is not cooked it is light brown andithi niche niyibone okanye weak brown. Now let's take now water as our model of water matter, You still remember we said a matter is anything that occupy space and has a volume or it has a mass. Now how can water can be a Solid. Can something like this (Globe and book) not exactly but it can , you might touch it siyayibona moos neh. Now you can make water a Solid when you take water and put it into a freezer and then it will be an ice.	No TSPCK Episode
<u>8-10 min</u> You can be able to touch and then that will be a Solid, but once the water is taken out of the freezer what will happen? It will melt-it will melt niyayibona moos neh? And once it melts it goes to a liquid stage and now from a liquid stage you boil siyayibona moos neh? Learners: Yes Teacher: When you boil this water what will happen? It will evaporate. Now you see some smoke that will tell there is a gas .Now it will be a process that will evaporate. Now you see yesterday it was raining moss neh and then there will be small ponds of water around where you are going to moss neh! You see now today there is the sun. The water will evaporates and it will suddenly, if it does not go down to the ground then it will go up as a gas. Now later on you will see that there was no water but there is in the morning you left there was water but in the afternoon you will see no water or there will be little bit of water; that means the process that happened is evaporation. Water evaporates and it will be a gas that's how we can be able to denote the particles of a model. Now let's take a solid. What happens to the solids? What makes a matter to be a solid? The particles of a solid are arranged in order;	**<u>Comment:</u>** In this discussion the focus is phase change using water as example **<u>In-depth Qualitative analysis:</u>** **Teacher Sophie's Action:** teacher Sophie is explaining phase change using water as example. Teacher Sophie is using textbook explanations and her own made up analogies to explain the concept. Teacher Sophie stated processes which causes different phases In the discussion above, Sophie is drawing from her knowledge of curricular saliency (CS) and using representations including analogies (REP) to explain and emphasise the concept of phase changes using particle explanations. In the TSPCK episode identified in this teaching segment, there are two TSPCK components which are used interactively to explain the concept of phase change. The TSPCK episode can be mapped as follows: 
<u>10-13 min</u> the particles of a solid are arranged in order. What do you mean? You see this desk? It is fine. The particles are made in order, let me take chalk, even if you tear it, yes you can see the particles you see? You can see somethings that are as holes moos neh? Learners: Yes	No TSPCK Episode

Teacher: But they are held closer to one another. Now there is a particle, tiny particles that will make this chalk to be a solid. When you look at this chalk, outside is not the same as inside. Now the thing is that; if you can see these holes are arranged in order, you cannot see spaces. There are no spaces between the particles. What makes the particles to have no lantuka- there are strong attractive force. There is a force that makes them not to move from one another. It's like when you take a cell. Now it's called a cell, what will happen? It can't split to see the spaces. When you call it, it will always come together. Now it means that there is a strong force that forces them to attract.	
<u>13-15 min</u> Then the particles are arranged. It is because the particles are arranged in order neh? And let us look at the liquid, what happens to the liquid? Something you know. A liquid takes a shape of something you use, of your container you used. If I take a bowl the water will take the shape of a bowl. If you take a square bowl, it will take all the four sided, it will enclose that means it will occupy the shape of the container you are using siyevana moos neh? Unlike the sand, what will happen if I take this water to a basin? It will try to form a shape of a basin and then when I take sand to a basin, it will just occupy a small place andithi? It can't spill around there and fill the shape that is the difference. It takes the shape of the container, what else? Andithi we said the particles are arranged in order, they are closer to one another moos neh?	No TSPCK Episode
<u>15 -18 min</u> here they are a bit far from one another. Particles are loosely packed that means there are spaces in between. There are no spaces neh? Now let's go to the gas. Something that you know when you …..there is a windy day then you close the door. What will happens when you open the door? When you open the door the air will move faster to occupy the room andithi. Learners: Yes Teacher: It means that there is little bit of gap between particles that's they move faster. Now if I can make an example of a solid to what we are familiar with. Now if I can take a grade 7s and I take a grade 9s into this class, there will be no space andithi? Learners: Yes Teacher: And then I say now I am there and say to someone in the corner "hey there is a snake" what will happen? You will try to run but there will be no space. What will happen? You will try to maneuver to move but it will be difficult but now if I can say as few as you are "there is a snake in the right corner" you will know where to run moos neh? You cannot collide with one another. You will be able to move around.	No TSPCK Episode
<u>18- 21 min</u> Now if I say all this class must go outside and I be left with Bhadaza and Kamva and then I say Bhadaza there is the snake. They can be able, it is easy for them to move moss neh? That example of you people (Bhadaza and Kamva) it will it is of the gas because now particles are able to move siyevana moos neh? This one that is you take all the classes it is the solid you can't move. They only when they are moving. Yes they are moving but when they are moving in which they are moving in a manner they are vibrating siyayibona moos. Your cellphone can vibrate because of that particles siyayibona moos neh? Now then, when there , that's why now the wind is easy for it to travel because there are few spaces it can be to walk around. That's how we denote the particles of matter. The model of matter and then now let's take ke ngoku what is ilantuka, you know you can reverse the reaction, a gas. Now let's say you boil water in a kettle, you are using a kettle	No TSPCK Episode

not the electric one- the one you put on the stove the when or a pot , you close your pot , you make sure that there is no water that is coming out. When you boil you will see, if it is a kettle you will see the smoke coming from the kettle andithi and then what will happen is that; it won't go all of it, there is one that will be on the lid and it will form the droplets and when it cools down it will form the droplets and then now when it falls there droplets down goes back to the liquid stage.	
<u>21-24 min</u> When now it is cold or warm you can be able to take it back to the freezer and then it will go back to the solid, but the difference now will be the mass or density. The solid you have put on the fridge, it won't be the same because the other one has gone through evaporation. Any question? I think in the absence of a question now let me take this example: you are about to make a juice. You have a concentrated juice, you can call it "Popos, Dallies" and then what happens when you put it in water- you put it to occupy one place moos neh! In order to have your combination andithi ufuna in order to make your combination you have make your situation to be faster then you will stir, what are your intentions to stir? It's to make the reaction to be the same- to be a solution; then the solution when your reaction has reached the ilantuka, isolution we call- it has reach equilibrium. Now this one it shows us there is water and then there is a drop. It can be a blood; it can be a concentrated then when you try to put it will make a circle, something like a circle. It try to combine with that one. Now when it combined it will be in that stage called equilibrium. Now you will see that there andithi iDallies kuye kuthwe xa ibhalwa pha it's a concentrated juice, if you are not aware of that you must look at that, you must look at the word concentrated ayixutwanga- it need water for ilantuka, you can't drink it when it is concentrated and when you put it, it is high concentrated and when you put it in water we said you are diluting it and then when you reach the solution that means that drop has reach and changed from a high concentration to a low concentration. Awusoze ngoku uthi [Xhosa word meaning you can never say] after you reach this lantuka uthi it's still a concentrated solution, you say it is a diluted solution. What happened there at your home, you were making your mom a juice, you put too much of a concentration and then what your mom will say? Yini yi-dilute andithi utsho? Learners: Yes	No TSPCK Episode
<u>24-27 min</u> Teacher: It means that you must put more water because it is still of a high concentrate moos neh! When you put water it means that you are making a low concentration. Now when your reaction it is of a high concentration to a low concentration- you call it a….. Learners: It's diffusion Teacher: It is diffusing- diffusion (another teacher comes in the class) Now any question? Any question? Learners: No Teacher: So now you can be able to diffuse solids from a high concentration to a low concentration- you take for an example sand. You take sand, you put it in water and then the sand now will be weaker because of intoni? Learners: Water Teacher: Water, you have diffused the solid into a weaker concentrator moos neh. It was ilantuka i-high concentration and now you diffuse it into – to be a low concentration. An example of a liquid concentrate we said "that example of juice you making your mom and then now it become strong and then would she say dilute it that means you are	No TSPCK Episode

making it to be weaker. So that is for today…. That is for today. If there are no questions, any questions? Learners: No Teachers: In the absence of questions ….Thank you very much!	

APPENDIX 16 : Analysis of teacher Sophie's enacted post-intervention lesson

Lesson 1	Comments / In-depth Qualitative Analysis
0-2 min Teacher: I think you are familiar with this word "matter" can you be able to explain what is a matter can you be explain what is a matter remember….anything that occupies space…...finish up Class: And mass Teacher: Or it might have a volume now that we call a matter (writing on BB the standard definition of matter) (writing on the blackboard the standard definition of matter) that is understandable….you are not allowed to make noise in a class, now this eeeeh if anything occupies a space) and has a mass , we call it a matter nhe we come to another word that is an atom, are you…can you be able to explain to me what is an atom, atoms are tiny particles that made a….that makes a…[class finishing: matter] nhe? I even made an example, in order for you to say chalk, it is the combination of tiny particles (writing on the blackboard and reading the explanation to the class after writing it down)	No TSPCK Episode
2 min – 4 min and why do we learn about these words, we understand that in our nature or in our natural living, we have these things that is a matter, we have an atom, we said an atom [meant matter] is anything that occupies a space and has a mass, most of the things that we use or most of the things that we happen to work with them they have a….they occupy a space and they have a mass, for example this chair [pointing at teacher's chair] occupies a certain part of a room, so and it has a …..volume or it has a ….mass siyayibona mos nhe, now these definition they help us to know how particles behave or what particles, how particles can be made or can be eeeeh a matter made of, we said they are atom, it's a tiny particles. We have different types of matter (s), my bag it's a matter, this book it's a matter, this one [showing a box of chalk] it's a matter, this bag it's a matter even if we can say these are the bags but they are different because they don't have the same material that's the word that comes [Pointing at 'matter and material' on Blackboard] siyayobona mos nhe they do not have the same material that's why you are able to say, this is a book this is a bag because material is not the same siyayibona mos nhe	**Comment:** In this teaching segment, teacher Sophie is giving rationale to why learners should learn about matter **In-depth Qualitative analysis:** **Teacher Sophie's Action:** Teacher Sophie asked learners why it was important that they learn about matter. The teacher then ties this explanation to definition of matter that matter is about understanding our nature since everything around us is matter. The teacher then used different materials to give examples to of matter generally. Conceptual progression of matter through real life example In the discussion above, teacher Sophie is using her knowledge of representations **(RP)** including analogies interactively with knowledge of curricular saliency **(CS)** to introduce to learners the importance of learning the topic. The resulting TSPCK Map for this episode is given as below:

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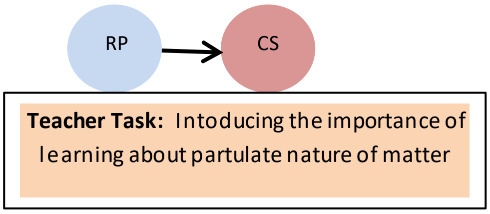

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<u>4-6 min</u>
but now lets look at the particles, the particles does not change, its only the material that make a….that's makes a certain eeeeh matter siyayibona, this one you call it a book, this one you call it a bag now if you notice we have three types of states that makes a matter we have a solid state, we have liquid state and also have the gas phase, now these atoms or these tiny particles they help us to be able to define what is happening to these three stages because they are different, you still remember when we have (mumbling) an example we said you come to this side all of you and you must combine and you must arrange yourselves, you still remember, I said you move, you still remember I said you move and then you notice that you always when you move you always even if you turn around you turn around such [teacher demonstrating turning around in fixed position] a way that you don't have a space and when you turn around you happen to touch one another then I said if you are doing that you are arranged in order and you are combined together I said that one is an example of a solid
Teacher: Now lets go to an example of liquid I said just spread a little bit, you still remember, you were the same Grade 8 I said just spread away and but and then you move now you see that you had an..a little bit of space that one we said it's a liquid
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<u>Comment:</u> In this discussion, the lesson focuses on particle nature of matter and materials and moves away from macroscopic level of matter into introducing particulate mnature of matter. The teacher also introduces phases of matter

I<u>n-depth Qualitative analysis:</u>
Teacher Sophie's Action: In this teaching segment teacher Sophie is introducing materials during solid phase. The teacher introduced to learners the concept that matter undergoes three phases and immediately explained that the particle explanations [microscopic level] helps us understands and define what is happening at each of these phases. The teacher then brought an analogy where she requested learners to arrange themselves in order and close to each other and made that analogy an example of particle arrangement in solid phase. The teacher instructed learners to turn around in their fixed positions and highlighted that at that moment they were representing particles in solid phase.

In the discusiion above teacher, Sophie is using her knowledge of curricular saliency (CS) interactively with knowledge of representations (RP) to help learners understand one of the difficult concepts to understand (WD) at Grade 8 level which is particle arrangement at microscopic level and visualisation of such concepts.
The resulting TSPCK Map for this episode is given as below:
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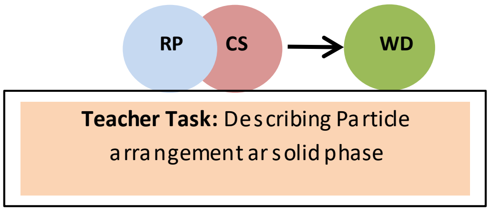
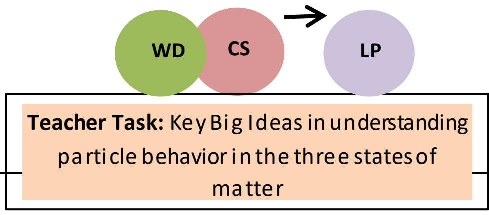
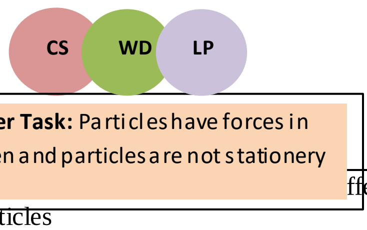
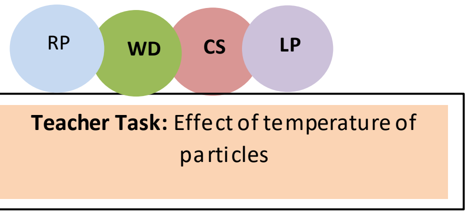
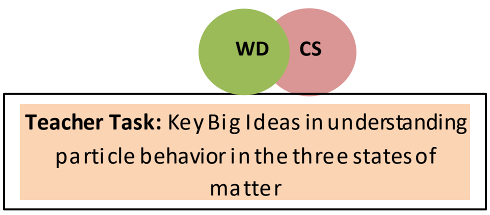
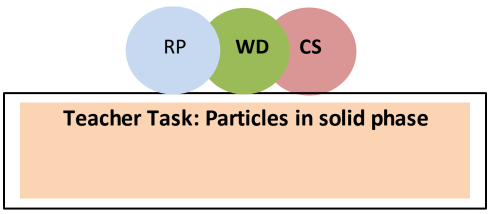
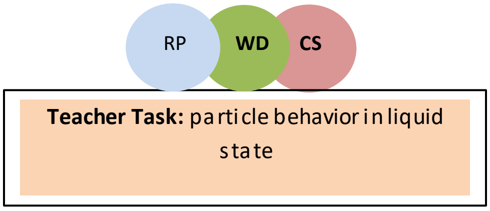
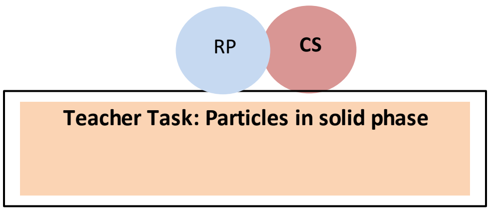
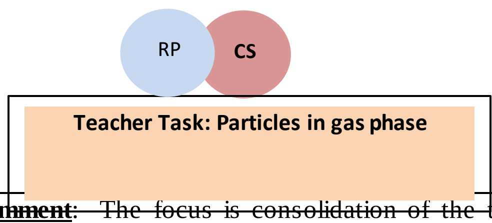
	
<u>6 – 9 min</u> Teacher: why are we learning this particles eeeeh models of particles of a matter it help us to explain okanye to describe what is happening in the three states and it helps us to explain how the particles how the states can change from one form to another [class finishing: form] now if you can take an example of a….an ice that we that we are all aware with no if you take eeeeh an ice from the….freezer what will happen? Class: It melts Teacher: It will melt and changes from a….. Class Singing: Solid to liquid Teacher: What actually happens to the particles that were there in the solid, what actually makes this particles if you say particles are changing, what makes these particles change to liquid now if I say this liquid now I leave my ice to melt all of it after that I put it on a hot temperature then now I will see the smoke now it means that my ice able to change from solids to the liquid and from the liquid to the gas, there is nothing you are going to use except this four aspects, you are going to look at your ice does your ice made up of tiny particles that incredible small and explain to that, yes the the ice is made up of small particles very small particles now does your ice have forces in between the particles, yes because now it is arranged in order it is arranged and yes the ice takes the shape of an…if you are using eeeeh the mug or you using a cup to make your ice it will take the shape of the glass now you will say yes they are there are forces because the particles of an ice are close together siyayibona mos nhe now you will explain that then you will come to aspect no.3 are the particles moving? Yes you will say the particles….. Class finishing: Are moving	**Comment:** In this discussion the teacher is explaining to learners phase change from solid phase to liquid phase **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** In this teaching segment, the teacher explained to learners that in order for matter to make transition from solid phase to liquid phase through to solid phase, key concepts in such processes were particle explanatiosn and these were summarized as four key aspects throughout the topic. The teacher highlighted matter was made up of tiny particles called atoms, secondly the teacher mentioned that there wre forces between these particles which influence the arrangement of particles and also mentioned that particles were always in motion. In the teaching segment above, there were three TSPCK components identified which the teacher used interactively to explain the concept of three states of matter in terms of particles, forces, effect of temperature and spaces generally. The lesson started by teacher Sophie summarizing the four outputs which she wanted learners to take out of the lesson when explaining phase change and differences in the phases of matter. In these outcomes teacher Sophie is using here knowledge of Big ideas **(CS)** to provide learners with overarching ideas in understanding the topic of phase change. Also as teacher Sophie highlights these explanations of matter at particle level, teacher Sophie keep addressing the possible learner misconceptions **(LP)** which learners might have in understanding these four overarching ideas in explaining matter using particle model. The teacher is also using her knowledge of what is difficult to understand (WD)by mapping out for learners concepts which are key to the entire lesson The use of TSPCK components in this episode can be mapped as follows: 

<u>9-11 min</u> the second part is that there are forces between the particles they [there] are forces between the particles noow the forces will depend to each state do you all understand, it will depend to each stage because the liquid state is not the same as solid state and it is not the same as gas phase now the forces they depend others will see that in other states there will be strong in others they will be weak so that you can even there are no forces, even if they are weak there are forces there is something that make them to be weak there is something that makes them to be strong, now the other part is that the particles are always moving you must be careful when we explain this it confuses a little bit the particles are no stationary they are moving and then now they depend on energy some of them their energy are very small and it seems that they are not moving siyayibona mos nhe then if the energy its high that's when you will see the..you will notice them or you feel them that the particles are moving they are not stationary siyevana mos nhe an example because we cant understand that lets say you have this desk we have water so now you can see the particles there now the desk what can you say for the desk, you can say the particles are stationary, that's not the case the case will be the particles are still moving but because of the forces are low they make them not to move	**Comment:** In this discussion, the teacher is explaining the forces in between particles and effect of temperature I**<u>n-depth Qualitative analysis</u>** **Teacher Amanda's Role**: Teacher Sophie told her students that another key aspect in understanding phases of matter was the concept of forces between particles of matter. Teacher stated that the forces between particles differed in each state and these were stringer in some phases and weaker in some. Teacher Sophie further explained that learners should understand that particles were not stationery in any of the phases and that their movement was dependent on energy. In the explanation above, teacher Sophie is using her knowledge of curricular saliency **(CS)** to explain the concept of forces between particles of matter in the three phases of matter. The teacher further uses her knowledge of curricular saliency to explain that particles of matter are always in motion and this knowledgewas interactively with the knowledge of what is difficult to understand **(WD)** is explaining to that even to the most solid materials at microscopic level, particles were not stationery. Teacher Sophie is also cautioning her learners about one of the common learner misconceptions **(LP)** which are reported in literature that learners tend to think particles are stationery especially in solid materials due to the macroscopic apperarance of these materials but at microscopic level this was not the case. The use of TSPCK components in this episode can be mapped as follows: 
<u>11 – 13 Min</u> now even if you take eeeeh lets take a plastic, now you are trying to heat the plastic what will happen to the plastic, it will become more and more and more and it will raise, what makes the plastic to move, its energy inside the particles not particles they are not becoming more but its only the energy, you cannot shrink the particles siyevana mos nhe, you can only shrink the matter, you cannot spill the particles but you can only spill the matter siyayibona mos nhe, that's why the plastic if we define it as solid andithi? We define as solid its not a liquid its no a gas then when you are not heating it seems as if it is not moving, the particles are not moving but when you heat it becomes more and more and it eventually blast siyayibona mos nhe then you would sin that particle, then you would see the sound then it tells you that there is an energy in that particle when the temperature is higher it creates more	**Comm**[illegible]ffect of energy on particles I**<u>n-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** Teacher Sophie gave her learners an analogy of a heated plastic containet to explain the effect of temperatures on particles of matter. Teacher Sophie told learners that as you heat the plastic container it blasts and eventually pop out. Teacher Sophie told learners that this was happening because as temperatures increased particles started gaining more energy. The teacher then cautioned students not to think that particles of matter were the ones that were increasing in size but the energy gained by particles as a result of heat. Teacher Sophie then mentioned common learner misconception which are widely reported about learning the topic, the scientific use of terms which only applies to material at

energy so that the particle will fastly move siyevana mos nhe I think you understand why particles are moving but particles are moving but particles you cant shrink them you cant spill tem ….its only material for example lets take an example of water now when you take water you are trying to spill water you cannot say the particles are spilling but you what we are going to say the water uchitha amanzi mos nhe awutsho nangoku uthi hayi ndicitha iparticles zamanzi the actual matter which is water I think you understand	macroscopic level as she told learners that particles cannot be shrinked or increased in size. In the discussion above teacher Sophie is using her knowledge of representations to make analogy (RP) while interactively using her knowledge of curricular saliency (CS) to explain ceffect of temperatures on particles. The teacher further cautions her learners about common misconception reported on literature that particles of matter cannot undergo physical changes such as shrinking and increasing in size (LP). The explanations and the accompanying analogy were also helping learners in understanding difficicult concepts to understand particle nature of matter (WD). All these components of TSPCK were used in interwoven fashion and thus can be mapped as follows: 
13 – 16 min then the last one is that there are spaces between these particles nhe there are spaces between the…the particles Someone will say there are no spaces now it will depend to a state how is the space but now there is the space what happens to this space, the space is filled with nothing, don't think that this spaces are filled with air, now if you say they are filled with air, imagine even air is a gas andithi? Class: Yes Teacher: No if you say they are filled with air what will happen to the gas, you will say the gas particles are filled with another gas you see how can be a gas filled with another gas, now the spaces absolutely they are blank, they don't have anything, siyayibona is nhe Class: Yes teacher Teacher: We can't see the spaces for solid but they are there we can't yes you can be able to see the spaces for liquid then actually you can fill the spaces for air because for instance when I open the door I allow the gas to come in, what will happen to the gas, it will fill this room, siyayibona mos nhe, then if we say these spaces are filled with a gas, ibizofika ingene phi igas? So it means that these spaces they are absolutely having nothing, now they are empty in other words if you say they have nothing they are empty now if you define the solid state, you are going to use this aspect that means 1. The atoms are made up of tiny particles 2. There are forces between the particles 3. You say the particles are moving 4. There are empty spaces and these empty spaces in the particles that means you will define in terms of four even if you want to see the changes of the states	**Comment:** In this discussion, the focus of the discussion was on the concept of spaces between particles. **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** Teacher Sophie told her learners that another key aspect in understand phases of matter is the fact that there were spaces between particles of matter and these depended on the phase of matter. Teacher also explained that these spaces were not filled in by anything they contained nothing. The teacher then consolidated the first section by recalling the four concepts which she mentioned as gatekeeping concepts in understanding particle nature of matter and particle behavior. In the teaching segment above, teacher Sophie is using her knowledge of curricular saliency to adress what is difficult to learn and is also giving her learners four gatekeeping concepts (WD) in understanding the concepts which are difficult to understand in their conceptual nature. In this discussion TSPCK components were used interactively in an interwoven fashion CS/WD and this TSPCK Episode can be mapped as follows: 
16 - 18 min	**Comment:** In this discussion, the focus of the discussion was on particle arrangement in solid phase.

now lets look at the solid state what happens to the solid state, what happens to the solid state actually in a microscopic [mumbles] part you don't see andithi you can see this is a bag but you can't see these particles arranging themselves you must use something to see these particles that they are arranged themselves, now lets look at the solid, Solid what or were we saying I think, before we do experiment you must recall what we were doing as a class you come here and you were solid, you still remember you come here and you are solid and then I said must arrange in rows there must be gap you still remember I was showing you that between the particles there are spaces siyevana mos nhe, now when you are trying to move you are moving in such a way that you don't have a space to move, that means you are held to one another then then if the particles the particles you can't compress in solid siyevana, you can't compress them, that means you can't squeeze them, can you squeeze this desk to make it smaller Class: No Teacher: No that means you can't do that to the particles of a solid, now they are in a fixed position, their position is not moving because there is no space for them to move around siyevana mos nhe they have a regular arrangement, I said you move as rows you move as rows there must be an equal spaces so I was trying to show you that they are in a fixed position you see you still remember mos nhe	**In-depth Qualitative analysis:** **Teacher Amanda's Role:** Teacher Sophie refered to the class demonstration to address what is difficult to learn (**WD**) to learn about partciles in solid state. For example, it is difficult for learners to understand that even in solids, particles are in constant motion. However, teacher Sophie asked learners in her demonstration to arrange themselves such that they were as close as they could to each other to represent fived volume for each particle. Also teacher Sophie asked learners to leave very little space between in each other and be ordered in rows and asked them to move (rotate) in fixed positions to demonstrate that particles in solids were only vibrating in fixed positions but not stationary. In this demonstration **(RP)**, teacher Sophie is using the demonstration to explain concepts **(CS)** teacher Sophie was addressing the difficulty of movement of particles during solid phase, thus demonstrating her knowledge of (**WD)**. In this TSPCK episode of teacher Sophie, there were three components of TSPCK identified and these were used interactively to explain particle arrangement and behavior in solid phase. The TSPCK Episode identified above was then mapped as follows: 
18 – 21 min I said now you must change to a gas I mean to the liquid when you were changing to a liquid what did I tell you, I said you must move just a little bit you must move just a little bit that you have a space but make sure when you move around you still remember I said you must touch your shoulder must touch one another if you are moving you must touch but you are having a space now I even said now what will happen to the liquid they are not arranged in order they are not arranged in order what happen if you are boiling water then you will see the bubbles nhe, meanwhile its boiling meanwhile it is boiling for a long time you see bubble moving around, siyayibona mos nhe that means ke we go to that aspect that says particles they are moving nhe siyayibona mos nhe particle are moving but they need energy because now you were using your stove you were using may be using wood to make fire now the water is boiling the more you put wood the more the water will boil you will see more bubbles strong bubbles it means that you increase energy the more they will have moving you see that movement that one is for a water or as an example of a liquid now you can't even compress can you compress water Class: No teacher	**Comment:** In this discussion, the focus of the discussion was on particle arrangement in liquid phase. **In-depth Qualitative analysis** **Teacher Amanda's Role:** Teacher Sophie refered to the class demonstration to address what is difficult to learn (**WD**) to learn about partciles in liquid phase. Teacher Sophie asked learners in her demonstration to arrange themselves such that they were arranged in a less orderly form. Teacher Sophie added that energy added made particles gain energy. In this demonstration **(RP)**, teacher Sophie is using the demonstration to explain concepts (CS) teacher Sophie was addressing the difficulty of movement of particles in the liquid phase, while explaining to learners properties of liquid form such as compressibility as a result of their particle nature. The approach she has chosen is also helping students to visualize what happens to particles at microscopic level thus demonstrating her knowledge of **WD**. In this TSPCK episode of teacher Sophie, there were three components of TSPCK identified and these were RP/WD/CS and were used interactively to explain particle arrangement and behavior in solid phase. The

Teacher: Can you make water to be small while you try to make it small it goes around your hands it moves so that you cant even have water in your hand you are trying to say I am having water using her hands) and I say go to the staff room you will see water will make sure that it spills up around because you cant squeeze it you see Class: Yes teacher	TSPCK Episode identified above was then mapped as follows: 
<u>Lesson 2</u>	
<u>0-2</u> Teacher: Now what else about what else do you know about the liquids what else do you know about the….it is not arranged in order the energy it is not they are able to move that means the energy will be can be be high or you can be able to increase even if you can be able to increase energy particles can move and vigorously and you can hear that sound ukhe uweve amanzi xa ebila moss Class: Yes Teacher: Then you can see the sound now what else can you cannot you can you not you notice or cannot you see or can you do with the liquids, now the liquids the force what happen to the force remember to the solid I said must arrange yourselves it means that there are strong forces that makes this particles not to move away from each other then what happens to the liquid the more as I say you move a little bit but it means you see andithi you know that force can be a force of attraction or force of repulsion the more you take magnet for instance lets take magnet when we take magnet for instance lets take magnet when we take magnet close to each other there is attraction then if you take magnet away there is a force of repulsion its simple like the particle the particles if they are scattered now the force become less or becomes weak you can even say there is no force because you can't see the effect of the forces but there is a force but is weak or I might say it is weaker, in solids the force is very strong then in liquids the force its weaker	**Comment:** In this discussion, the focus of the discussion was on particle arrangement and forces of between particls in liquid phase. **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** Teacher Sophie further told learners that forces between particles of liquid were weaker than particles in solid phase. Teacher Sophie brough her demostation together with some analogies to explain this concept to her learners. In this TSPCK episode of teacher Sophie was using her knowledge of curricular saliency **(CS)** interactively with the knowledge of representations **(RP)** to explain the concept of intermolecular forces between particles of matter in liquid state. The TSPCK Episode identified above was then mapped as follows: 
<u>2-4</u> then lets go to the gases what can we say to the gases I said when I say open up the door or the window you will see that the ags that is coming trhough the window will try to make fill will fill this room everybody uzothi ndiyagodola cz uva la moya mos nhe. Class: Yes teacher Teacher: So it means that everyone can feel now if now I can say ndithi hambokha Isanti pha ndithi yigalele apha what will happen. Izo formisha	No TSPCK Episode

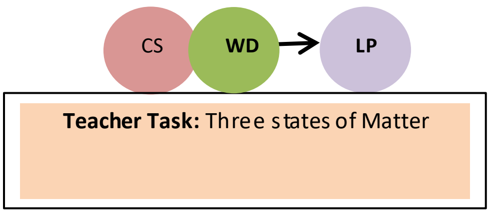
izogcwalisa la ndawo uyigalele kuyo mos nh? Amanzi azothini azozama by all means to occupy the space but if uba ngaba mancinci mos nhe then ke ngoku anagkwazi ufillisha the gas will make sure that it feels the space that it has or the given space now what happens is that because the gas they move at high energy that's why if kukhona kuyagqitha mos nhe if you are trying to run away actually it will catch you and then it will pass you to another place because they [there] is more there is fast and if the energy is high it will make the particles to be fast siyayibona mos nhe, so now for the gas the forces are very weak, because the particles are scattered they are trying to fill in the gas here [showing a box of chalk] what will happen it will try to fill and so that it will make a eeeeh it will make this container to blast	
<u>4 – 6 min</u> now if you can see when you are when you are lets say you are putting in, you are blowing a balloon what happen if you blow, you will blow in such a way that the air is filled what happen to the balloon if it is fully blown Class: Mumbling …Izogqabhuka Teacher: It will blast mos nhe, what makes that because now the air or the gas that is inside the balloon it doesn't have a space and remember the gas particles they need more space to move and you move very fast now it will make now your particles to it will make your matter as a balloon to blast now, you see the differences, all this thing you will explain them using the four aspects now you will look at the solid as the particles that are many, we have experienced that every matter has ntoni? Has tiny particles……….as anything it occupies a space and it has a mass now we have you will define the particles as they have the force its either this one a solid has strong forces, the liquids have weaker and then now the gases they have absolutely weak and very weak forces now you will again explain that there are spaces they are spaces between the particles and then lastly what we what we are we going there is……eeeeh particles are always moving that is the only thing if you explain the solid you are going to use this eeeeh four aspects now what,	**Comment:** In this discussion, the focus of the discussion was on particle arrangement and forces of between particls in liquid phase. **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** Teacher Sophie gave students an analogy of a balloon filled up with gas until it bursts. The teacher used this analogy to teach learners that the balloon was bursting because the volume of the balloon was filled and had no more space to accommodate them and because particles in gases had larger spaces in between because forces holging particles were very weak. The teacher also mentioned that the in gas particles were moving quite faster. Teacher Sophie is using her knowledge of gatekeeping concepts in particle nature of matter to adress what is difficult to learn when dealing with the concept of particles in gase phase. In this TSPCK episode of teacher, Sophie was using her knowledge of curricular saliency **(CS)** interactively with the knowledge of representations **(RP)** to explain particle behavior in gases. The TSPCK Episode identified above was then mapped as follows: 
<u>6 – 9 min</u> Teacher: why are we learning this particles eeeeh models particles of a matter it help us to explain okanye [a xhosa word meaning or] to describe what is happening in the three states and it helps us to explain how the particles how the states can change from one form to another [class finishing off: form] now if you can take an example of a….an ice that we that we are all aware with no if you take eeeeh an ice from the….freezer what will happen? Class: It melts Teacher: It will melt and changes from a….. Class Singing: Solid to liquid	**<u>Comment</u>**: The focus is consolidation of the three phases of matter **<u>In-depth Qualitative Analysis:</u>** **Teacher Sophie's Action:** In the teaching segments above teacher, Sophie explained the three phases one by one and this teaching segment the teacher gave learners consolidated explanations of the three states of matter using the three concepts which the teacher gave at the beginning of the lesson as gatekeeping concepts in understanding particle nature of matter. The teacher used the the concept of intermolecular forces and arrangement of particles in different phases

<table>
<tr>
<td>Teacher: What actually happens to the particles that were there in the solid, what actually makes this particles if you say particles are changing, what makes these particles change to liquid now if I say this liquid now I leave my ice to melt all of it after that I put it on a hot temperature then now I will see the smoke now it means that my ice able to change from solids to the liquid and from the liquid to the gas, there is nothing you are going to use except this four aspects, you are going to look at your ice does your ice made up of tiny particles that incredible small and explain to that, yes the the ice is made up of small particles very small particles now does your ice have forces in between the particles, yes because now it is arranged in order it is arranged and yes the ice takes the shape of an…if you are using eeeeh the mug or you using a cup to make your ice it will take the shape of the glass now you will say yes they are there are forces because the particles of an ice are close together siyayibona mos nhe now you will explain that then you will come to aspect no.3 are the particles moving? Yes you will say the particles…
Class finishing: Are moving</td>
<td>of matter and their prospective physical processes, giving reasons using particle forces. Teacher Sophie stated that if oe takes out ice from the freezer, the ice melts and changes from

Learners' Response: Learners responded that it would change from solid to liquid (LP)

In the teaching segment above, teacher Sophie used her knowledge of curricular saliency (CS) to consoslidate the lesson about three states of matter and impact of intermolecular forces inclusing the arramgement of particles. The teacher is using gatekeeping concepts to facilitate the discussion of particle behavior in gas phase and thus addressing what is difficult to learn (WD).

In this teaching segment, there were three components of TSPCK at play and these were CS/WD-LP. The TSPCK Map for this episode is:


</td>
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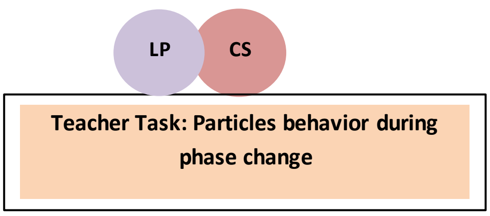
<tr>
<td><u>11 – 13 min</u>
now you will notice that when I say the particles does not change the same ice you use the particles of an ice you see them to it changes to be liquid if they are 9 atoms of an ice even if it melts it will have 9 the particles does not change now it really confuses because that you can see that some other books they will tell you that or they will show you that the particles, yhhhaaa this is an example now if you can count this one for the solid you will see they are many and if you count this one they become fewer {took a snapshot of this from textbook] and this one they become less than the other that's not the case, here they are trying to show you the arrangement that's why they are making many because if I can call three of you and I said you must move around, you can't show it siyayibona mos nhe but it can easily to be shown if it's a liquid or a gas because you can easily to walk if you are three but if you are 10</td>
<td>Comment: The discussion is on the fact that particles do not change size.

<u>In-depth Qualitative Analysis</u>
Teacher: While teacher Sophie was teaching the concept of phase change, she took some time to address one of the learner misconceptions widely reported when teaching this concept whereby learners think changing phases meant particles also changed and were also particles were becoming fewer. This meant teacher Sophie was drawing from her knowledge of learner misconceptions in the topic (LP). Teacher Sophie used a representation from the school textbook as a way of addressing the source of this learner misconception as she took out a textbook where there were more particles in solids and few and in liquids and fewer in gases and explained the reason for the textbook to give such representation. Teacher Sophie used her knowledge of curricular saliency (CS) to address the learner misconception and provide learners with correct understanding.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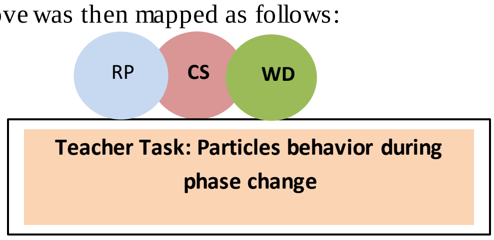
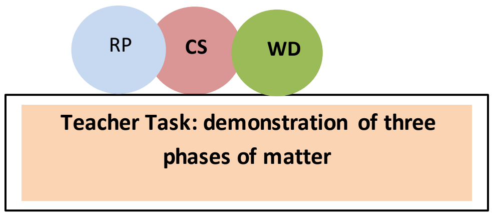
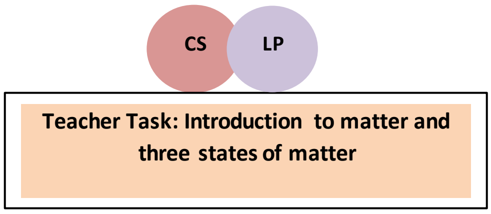
<u>**13– 16 min**</u> it will make you difficult to move around you see that is the particle the same particles that is used in a solid are will be the same particles that is used in the liquid phase and they will be the same particles of a gas, if the matter is the same so it means that the particles does not change, does not get eeeeh lost if you see oooh okay this is a gas in order for them to move it means that the particles must be few that is not a case some particles they are trying to occupy a space now if you for example ndikwenzele for you] iexample nge santi ndifuna ukuyifaka ebhotileni xa ndigqiboyifaka ihlala pha ezantsi mos nhe if it's a gas kuzokwenzekantoni ndizoyivala then xa se izele izawuthini, izokwenza ukuba isiciko sithini isikhabe [a xhosa sentence meaning let me make you an example with sand if you put it in a bottle when you have done putting it inside the bottle it will sit at the bottom, if it's a gas what will happen?i will close it and when its full what will happen it will it will push the lid of the bottle] meaning to make because it needs more space siyayibona mos anhe so any questions okay if you all understood I think that is all for particles, that's what you must be able to know, these four aspects particles that are very important, particles are made up of tiny particles there are tiny particles in a matter nhe, forces there are forces, particles are moving then there are spaces between the particles if you have those four aspects you can explain the solids the liquids as well as the gases using only four aspects that's all you can answer you go to the compounds you go to the elements you go to any any absolutely anything you will always define the four siyayibona mos anhe you always define the four then they will give you the model of a particle, how is the particle how does this theory of the particle happen so it will mean you use those four aspects	**Comment:** In this segment, the focus was on consolidating the discusiion about the fact that phase change doe not mean particles size changes. <u>**In-depth Qualitative analysis:**</u> **Teacher Amanda's Role:** Teacher Sophie reffered to her classroom demonstration **(RP)** that when particles when closely packed it would be difficult to move in between particles because there are little spaces in between. Teacher Sophie added that the amount of particles of a particular substance in solid phase will be the same amount in liquid phase nothing will change except spaces and forces between particles. Teacher Sophie told learners that particles do not get lost which is a concept that speaks to Law of Conservation of mass. The teacher also mentioned that again whether learners were learning about elements or compounds, the key concepts which they must keep in mind were the spaces between particles, intermolecular forces, matter being made up of particles called atoms by doing so teacher Sophie was giving her learners a less crowded pathway to navigate the topic of particulate nature of matter and thus, dwaring from her knowledge of **(WD)** to learn. In the teaching segment above, teacher Sophie is using her knowledge of curricular saliency to adress a learner misconception which is widey known in the field which meant the teacher was drawing from her knowledge of **(CS)** In this TSPCK episode of teacher, Sophie was using her knowledge of curricular saliency **(CS)** interactively with the knowledge of representations **(RP)** to explain particle behavior in gases while addressing **(WD)** in the topic of particle nature of matter generally. These components were used in the order RP/CS/WD The TSPCK Episode identified above was then mapped as follows: 
<u>**16 – 17 min**</u> The teacher instructed learners to come to the front, and arranged learners in order instructing them that "I do not want to see space" the teacher asked learners to come closer to one another and told the class that with such an arrangement learners were "solid" the teacher asked learners to move around, move around move around while fixed in same positions and instructed them to stop	No TSPCK Episode
<u>**17- 18 min**</u> Teacher: Now you are trying to change your state, move a bit and give a space and then move around move around , move around	No TSPCK Episode

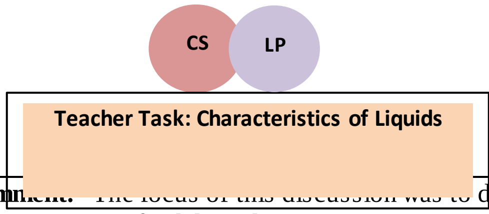
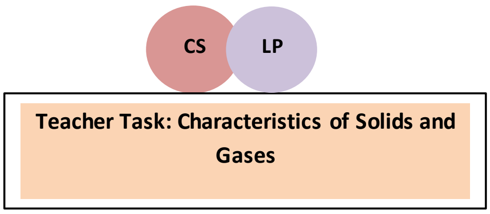
You are boiling now you are boiling (learners started moving faster while laughing) X3 Yamnkela is not boiling back to your place now	
<u>18 – 19 min</u> then get scattered Move away as much as you want move away as much….you are you are gases now you are gases and then move around move around move around move around don't touch any one make sure you do not touch any one (students kept moving freely around without colliding with one another) go back your place now That's how you change, khange sithi omnye umntu makaphume ecaleni sithi now sithi ugqiba ispace ke ngoku now, you were the same Grade 8 when you were liquid and then you were solid you were moving you were closely packed now you changed to the liquid you were the same particles you are particle you are particle you are particle you are all individual particles but then you come to make a matter siyayibona mos nhe but its only the gap that you are giving one another when you were gases you saw that you don't touch anybody cz you will have the space niyayibona mos nhe so that was the presentation for the teacher and Grade 9 how the phases change from one to another thank you bantwana bam go and sit down	**Comment:** The focus of this was conclusing the lesson with a demonstration of three phases of matter using students to represent particles. **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** After teacher, Sophie highlighted the four-gatekeeping concepts of particle nature of matter, these these were then used to teach and explain the concept of three states of matter. Teacher Sophie started made a demonstration using the Grade pupils to emphasize the idea of space arrangement in particles in the three states of matter, the movement of particles. The teacher also emphasized in the demonstration that as these students were representing particles during the different phases of matter, however they remained the same Grade 8 class that meant particles do no change size or their original state during phase change. 

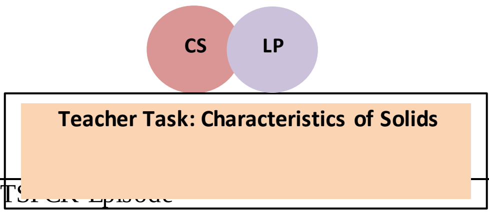
APPENDIX 17: Analysis of teacher Noreen's enacted pre-intervention lesson

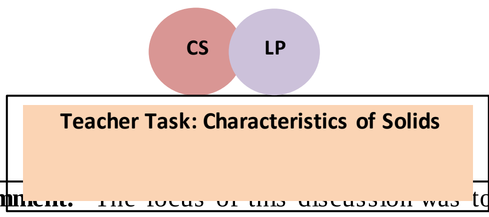
Lesson 1	Comments / In-depth Qualitative Analysis
0-3Min Teacher: Ummm good afternoon, what is matter guys what is matter? Suwatshazela, subamba umzimba phakamisa isandla uthethe sukoyika akhonto azoyithetha uMiss uzozihlalela pha athule [a xhosa sentence meaning do not feel intimidated, do not hold yourself, raise up your hand and speak, the lady (referring to me) will sit there and keep quiet]. Leaner: Matter is anything occupies space. Teacher: is anything that occupies space uSesethu uthi matter occupies space, what else can you say about matter, yintoni enye oyaziyo? Ok what you mean when you say it occupies space? Ok masithetheni ngesiXhosa yinto enjani le uthi yi- matter xa uyibiza okanye ndinike ke examples zayo lento uthi yimatter, ndiphe iexamples zalento uthi yi matter akho nomntu lo ufuna uzama? Mmm? Bulela akukho nto ofuna uyithetha about matter? Learner (XX): Miss nzoxela ba…………………….. xa usithi [a xhosa word meaning Miss I will say that] when you say it occupies spaces matter its everywhere. Teacher: Matter is everywhere? Ok uthi uBulela matter is everywhere, matter occupies space, Aya can you say anything about matter? Ndiyarhalela yhaz ukunikwa umzekelo we matter so that sibe ne picture of what we are talking about. Sima ingathi you want to say something? Akhomntu unondinika umzekelo we matter elapha? Leaners: lithosphere Teacher: lithosphere? Ahhhhh? Huh? Ok kuthwa matter occupies space and has mass, xa sithetha nge matter kaloku it's something that siyakwazi ukuyibamba, like nantsi (showing a bottle of spirit) yintoni ke le ilapha ngaphakathi? Learners: Spirit	**Comment:** The focus of this discussion was introducing matter and examples of matter. **<u>In-depth Qualitative analysis:</u>** **Teacher Amanda's Role:** Teacher Noreen asked her learners what is matter? **Learners' Response:** Learners replied that matter was everything that occupies space and is everywhere. In the teaching segment above teacher Noreen asked learners, what matter is and as learners replied the teacher then continued to ask learners other questions without confirmimg the learner responses thus only one component is visible in this discussion that is curricular saliency and thus this discussion had No TSPCK episode.
03:24-05:56 min Teacher: Spirit is in a form of what? Huh? Learners : Liquid Teacher: Liquid? Xa sithetha nge-liquid [a xhosa word meaning we not talking about water, Huh? Xa sithetha nge- liquid na are we not talking about water guys? Learners: we talk about water Teacher: Water only? Learners: Yes other says No Teacher: Ndibhidekile ke ngoku bakhona abathi yes. You are saying methylated spirit is a liquid andithi? And you are saying when we're talking about liquid we are referring to water only? Learners: No. Teacher: ndipheni ke other examples of liquid, ezinye izinto ezingamanzi. Nithe kaloku nina ispirit is the liquid andithi? Nathi water is a liquid andithi? Ndipheni ke other liquids? Leaners: Paraffin, Petrol, oil Teacher: So zininzi aneh?Meaning that if we are, when talking about liquid its not only about water andithi? Which means kenguku means paraffin, spirit, oil, , ubisi yi-matter le sithetha ngayo neh?(kids answer yes) Ok	No TSPCK Episode

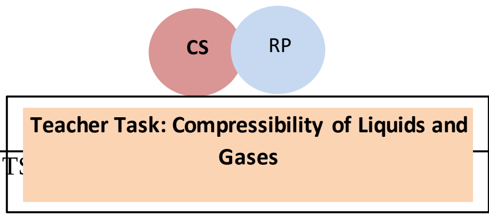
yeyiphi enye iform of matter, nitshilo nathi ezi zi-liquids, anditsho zi-liquids ezi, zeziphi ezinye izinto enithi zi matter xa nizibiza? Leaners: Gas Teacher: yiGas ? (Class answer yes teacher) what are we talking about xa sisithi gas?(class answer Air) Air? Ebetheni kanene uBulela? Ngubani okhumbulayo uba ebetheni uBulela. Hands up? Yes sisi? Girl (answered): We found everywhere. Teacher: What do we find everywhere, what is that we find everywhere huh? Learners: Matter Teacher: we find matter everywhere.	
05:56 - 08:47min If you saying pha kwi gases sine Air where do we find air? I find it everywhere andithi? So unyanisile kengoku uBulela? (Class answer yes). Fine ezinye igases that we know? Learners: Carbon dioxide Teacher: Can we put our hands up when you want to say something. Carbon dioxide, what else? Learners: Water vapor Teacher: Ndibhale, Water vapor? Where do we get water vapor? Leaners: Boiling water Teacher: So boiling water is water vapor, Yamkela boiling water is water vapor? Learner:No Teacher: Hayini aba bantu abafuni kwa uthetha bonke bayandibuka qha ngathi bayaqala undibona. We are saying boiling water is water vapor? Andiva Lukhanyo? Lukhanyo: We get water vapor from boiling water. Teacher: We get water vapor from boiling water. (Class answer yes teacher) unyanisile? Grade 8s yintoni iwater vapor? (class mumbling). Ngu mophu? Leaners: Si steam Teacher: Si-steam? Siyifumana xa kutheni iwater vapour huh? Xa kubila amanzi kuphume? Class: Water vapor Teacher: then ke ngoku ngula mophu lo sithi yiGas?(yes teacher) khanindiphe enye igas mhlawumbi?No chorus kaloku guys, yes buti? Leaners: Oxygen Teacher: Haibo, ok oright I can see uba abantu bane gases abazaziyo	No TSPCK Episode
9-12 Min and then you said nina not mna kwi matter sesiyayibhaqa moos intoba we are talking about matter andithi? (class answer yes teacher). Kwi matter sine liquid, you gave me all the examples, kwi-liquid you gave me examples then yeyiphi enye into? Leaners: Solids Teacher: Can you give me the examples of solids? Leaners: Yes (ice, stone and naming them) Teacher: So wena ubusazi istone (asking one child)? Ibingekho enye into onoyilungisa? Into ebangela ndimane ndimjonga wenjenje (putting a hand around the mouth) uSiba ngapha kwesandla qha akafuni uthetha nam. Nithe ice, ne soil,…….. Leaners: Salt	**Comment:** The focus of this discussion was to consolidate different bits of concepts of the first 9 minutes **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** After 9 minutes of naming examples of liquids, solids and gases teacher Noreen then focused learners attention by stating that she wanted the class to look into three things which they were discussing and she mentioned solids, liquids and gases. The teacher the asked how many states of matter **(CS).** **Learners' Response**: Learners responded that there were three states and teacher confirmed this knowledge and named the three states **(LP)** **Teacher Noreen's Action:** The teacher then asked learners to look at the differences in these three different states

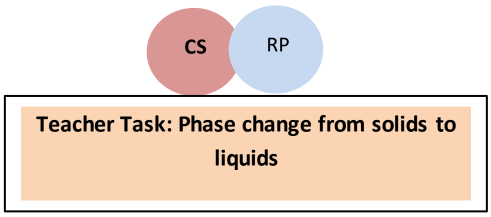
Teacher: Thethani. Alright masijongeni ke ngoku the three things we talking about sithe zi- Liquid, ziGases , ziSolids andithi? Zingaphi istates of matter? Leaners: Three Teacher: three states of matter solid, liquid and gases. Can we look at the differences, yitoni le ilapha ibanguba sithi this is liquid ubone nje uba there is no way you can say this is a gas kucacile nje this is a liquid; ujonge nje kucace nje uba ngamanzi la ndiwajongileyo, awunakutsho tu uba this is a solid or this is a gas, ubone nje ngamanzi la? Ndifuna the differences, mhlawumbi masithi differentiate between the liquids and gases zehluka njani? Amanzi atheni, gases zitheni? Yes ntombi?	
11:32 – 13:37Min Leaner: Water is something that you can see but you cannot touch. Teacher: You can see nge-luck ndinawo amanzi, something you can see when you say you cannot touch, andizokwazi ukuwabamba kanje (demonstrating). Learner: No miss awunokwazi ukuba uwabambe kanje {you cannot touch them like this} Teacher: (demonstrating) Wabambe ke la (call one child) ndifuna uthathe amanzi la sibone uba awathatheki neh. Awathatheki neh? Learners: Yes teacher Teacher: O-right what else can you say about water? mhh Teacher: Iphendulwe Learner: mmm liquids has no definite shape they take the shape of the container Teacher: It has no definite shape, they have no definite shape, they take the shape of the container. Siwagalela apha ngoku amile kanje andithi but masifake kwi test tube nalapha, apha bevulekile (glass) andithi but xa siwagalela apha amila kanje ngale andithi (test tube) if siwagalela eskhaftinini kuzakwenzeka ntoni? Aniyithandi i……. Ansari. Abantu bathanda ucula abathandi uvela. Ok we are saying iliquids, they take the shape of the container,	No TSPCK Episode
13:37-17:16 waphida wathi atheni kanene? Learner: You can see but you cannot touch. Teacher: You can see but you cannot touch. Mandiyibhale into yabantu, see you can not touch. No definite shape. Yintoni enye onoyithetha ngamanzi? Uyakwazi ukuwacinezela amanzi?(class answer no) kuthini ukucinezela? Learners: Press Teacher: Masithi compress neh and then we saying that water is not compressible. Compressible, compressible and then masithi liquids are not compressible, liquids are not compressible andithi? (class answer yes teacher) Okay masi comparishe ke ngoku with the gases , size kwi-gases kwenzeka ntoni kwi gases? Sithe liquids they take the shape of the container, they have no definite shape, ….. you cant touch , they are not compressable-awuzukwazi uwacinezela andithi? learners: Yes teacher Teacher: Let us look on gases, uthini ngeGases?uphi na uMconase kutheni endilahlekile? Ohh yes Lukhanyo akhonto unoyithetha about gases kula? Yes buti?	**Comment:** The focus of this discussion was to discuss the characteristics of the three states of matter **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** At the end of the previpus segments teacher Noreen wanted her learners to look into comparison in the differences between the three states of matter. Teacher Noreen asked if water were touchable (meaning to hold them without their container) **Learners' Response:** Learners responded see water but you cannot touch them **(LP)** **Teacher Noreen's Role:** The teacher told learners that liquids had no definite shape but rather take the shape of the container. Teacher then asked if it was possible to compress water and told them that water is not compressible. In the teaching segment above, teacher Noreen is using two TSPCK components interactively to explain the characteristics of liquids which are unique from the other gases and solids. These TSPCK components were CS/LP

Learner: we can feel Mem but see, can't see. Teacher: The gas Class: Yes Miss Teacher: How do you feel it? How do you feel it? Learner: we feel the gas by its movement its like a wind mem Teacher: so air is a gas? (class answer yes	
17:16-20:58 xa singakwazi sithe mos xa singakwazi ukuyicinezela sathi it is not compressible andithi? Class: Yes Miss Teacher: Aright iGas is not visible, sithetha ukuthini ke ngoku? Class: Ayibonakali Teacher: Ayibonakali andithi? (class answer yes) Teacher: yeyiphi enye into onoyithetha about the gas? Pule? Pule: Gas is with the atmosphere, you breathe it. Teacher: You breathe it?do you only breathe a gas? Which gas do we breathe in? Class: Oxygen Teacher: Oooh niyayayibona iyi one qha into eniyithethileyo about oxygen that it is not visible. Ok can we go to the Solids now? (class answer yes). Tecaher: mmmh, Yes buti? Learner: It's something you can see and touch. Teacher: which one can you see and touch? Learber: Ice Teacher: Is ice a gas or liquid or solid? (class answer –solid) Teacher: which means iSolids are visible, they are touchable what else can you say? Kuzothetha nina kule game (pointing a group that has been quite) What can you say about Solids? Andikuva? You stand up and talk, stand up buti , thetha lento ufuna ukuyithetha Learner: They have strength Teacher: They are strong? They have strength? Uthi they have strength Ndirhalela uyazi ufuna uthi zitheni? Teacher: Thetha ngesiXhosa (class answer: ziqinile) Ziqinile iSolids unyanisile? (class answer:yes)Alright you wanted to say something? Learner: something that cannot break. Teacher: You are saying solids are things that cannot break?So iglass cannot break? I mean it is not a solid? iGlass is a solid? (class answer yes teacher) like ezi glass tube ziphambi kwenu zi-liquids? Ezi (lifting up a glass tube)? Zintoni ezi? Class: **Solids** Teacher: Alright but iyephuka iglass andithi? So asinotsho sithi siyibona ngoba yona ayizokophuka,	**Comment:** The focus of this discussion was to discuss the characteristics of solids and gases **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** Theteacher then asked learners to focus into gases and asked learners what they knew about gases. **Leraners Role**: Learners responded that you can feel the gas but cannot see them and the way they were felt was by their movement like wind. Learners further gave examples of gases and mentioned atmosphere, and Oxygen, the teacher then stated that learners did not say anything about gases except that they said gases were not visible. However, the teacher left this statement hanging without addressing or confirming correct scientific explanations. **Teacher Noreen' Action**: The teacher then asked learners to now look at Solids and asked what could learners knew about solids. **Learners' Role:** Learners stated that solids you could see and touch them. Some mentioned that Ice is solid. Teacher Noreen confimed these characteristics using scientific terms as she stated *"which means solids are visible and touchable"*. **(LP)** Learners further stated that solids were strong and had strength In the teaching segment above, teacher Noreen is using her knowledge of curricular saliency to confirm correct scientific concepts which were exposed as she probed for learner prior knowledge. 
20:58 – 22:29 Teacher: what else you can say about **Solids?** Zinayo iweight? Class: Yes Teacher: ungakwazi ukuzi measure-isha iweight yazo? Class: no Teacher: MMM	**Comment:** The focus of this discussion was to discuss the characteristics of solids **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** The teacher then asked what eslse could they say about solids and further asked if they had weight Learners' Role: The learners responded with a yes

Class: Ungakwazi Teacher: Andiva pha thetha lento beniyithetha?. Snalo thetha kaloku when we say xa ndibuza intoba is it measureable ndifuna ukwazi lonto yoba if sithatha this test tube siyibeke escale-in sijonge uba ithini iweight yayo? Class: Yes Teacher: Ibisithini kanene idefination yethu of matter kanene?Besithe what is matter guys? Class: matter is anything that occupies space Teacher: Matter is anything, anything uyeva? Noba yintoni. Anything that occupies space and has mass, which means it occupies space uphinde futhi ibe ne-mass meaning that it is measurable because once you talk of measure it means siyayazi kengoku uba inzima kangakanani na, siyevana?	Teacher Noreen's Action: The teacher further asked if solids were measurable and learner said No. The teacher then confronted this misconception by reminding learners about the definition of matter as she asked what we say matter is (asking learners) **Leraners Role**: The learners responded that matter is anything that occupies space. (LP) **Teacher Noreen' Action**: The teacher then confronted learner knowledge by expanding the definition of matter to answer the question of measrurability of solids stating that "*Matter is anything, anything uyeva [a xhosa word meaning do you hear me]? Noba yintoni [a xhosa word meaning anything]. Anything that occupies space and has mass, which means it occupies space uphinde futhi ibe ne-mass meaning that it is measurable because once you talk of measure it means siyayazi kengoku uba inzima kangakanani na, siyevana*? In the teaching segment above, teacher Noreen is using her knowledge of curricular saliency to confirm correct scientific concepts, which were exposed as she probed for learner prior knowledge and in explaining charactistics of solids using the basic definition of matter. 
22:29 -25:20 Teacher: Alright ndifuna sijonge ke ngoku the particles of matter. We said it is measureable and occupies space. Fine, what about the particles arrangement, uyabona xa usarha umthi nhe? kwenzekani kuphuma ntoni? Class: Ingququ Teacher: Ingququ zezi particles zenze la mthi eziya andithi? Ungathini ke ngoku, akhonto unoyithetha xa ucinga nje engqondweni yakho? Ungathini, ungathini ngazo? Ungathi umthi utheni udibanisa nala ngququ njengoba sisithi xa usarha kubakho lanto iphephethekayo ithi? Andithi, Ungathini? Class: They are made of particles Teacher: Into ebangela ndilaqaze ukhona umntu othi shape qha andazi noba utsho apha(pointing one group) or utsho phaya(pointing another group) ngoku ndirhalela uyazi what about shape and particles? Ndimbonile utsho pha qha andikho sure ngoku kea bantu abafuni uthetha Mem. Queen: Babangandoyiki andizobabetha. Teacher: Nisamoyika uMem? Kudala elapha nje akathethi uzithulele, uzihlelele, uzihlelele neh akenzi mntu nto. Ibisithini lanto? Ngubani lamntu ebefuna uthetha about shape? Aright bathule ke Mem abantwana. Nantsi idesika neh, moos liplanga eli silibonayo? Linayo la ngququ kodwa avivelanga yathathwa la ngququ , eza particles zenziwa isgaqa noba sinjani andithi? There is a particular arrangement of particles so that kuphume le table of this	No TSPCK Episode

shape anditsho? Which means iparticles zalapha are arranged in a certain manner, kukhona indlela eku-arrange-we ngayo iparticles pha kwiSolids andithi.	
25:20 – 27:22 Ucinga zingakanani ezi [a xhosa word meaning what do you think is the size] spaces between the particles apha [a xhosa word meaning] kwi Solids? zikhona, zikhona [a xhosa word meaning are there any]? Class: No Teacher: Zikhona ispaces? So are you saying zidibene nca nca? (class answer yes) TEACHER: Uyaphosisa, there are very small spaces between particles phaya, kuxinene qha uyeva? Kuxinene and there is a difference uba ngaba singajonga pha kwi gases. I gases like uba singenza umzekelo, singathi iparticles is Solid, kuxinene, they are closely packed together niyayibona and yet pha kwigases iarrangement yazo noko they are much spaces between them, niyayibona? And naphaya kwi liquids ikhona I arrangement of particles although ispaces zakhona zingadanga zafana nakwi gases but nakwi liquids ikhona i-arrangement eyenziweyo pha. Asinakuze sithi ziyafana ne-Gases kodwa Gases zona they are bigger, kukhona isyringe esilapha aninazo isyringe apha ezitafileni zenu. Aninaso (asking groups if they have a syringe in front of them) Class: No Teacher: Ninaso nina?(distributing syringe in each group) Ndifuna sijonge the difference between i-compressible of gases ne, need? and then siphinde sithethe nge arrangement of these particles.	**Comment:** The focus of this discussion was to discuss the particles in solid materials **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** The teacher asked learners what dod they think were the size of spaces in solids if there wee any? what eslse could they say about solids and further asked if they had weight Learners' Role: The learners responded with a yes Teacher Noreen's Action: The teacher further asked if solids were measurable and learner said No. The teacher then confronted this misconception by reminding learners about the definition of matter as she asked what we say matter is (asking learners) **Leraners Role**: The learners responded that matter is anything that occupies space. (LP) **Teacher Noreen' Action**: The teacher then confronted learner knowledge by expanding the definition of matter to answer the question of measrurability of solids stating that "*Matter is anything, anything uyeva [a xhosa word meaning do you hear me]? Noba yintoni [a xhosa word meaning anything]. Anything that occupies space and has mass, which means it occupies space uphinde futhi ibe ne-mass meaning that it is measurable because once you talk of measure it means siyayazi kengoku uba inzima kangakanani na, siyevana*? In the teaching segment above, teacher Noreen is using her knowledge of curricular saliency to confirm correct scientific concepts, which were exposed as she probed for learner prior knowledge and in explaining charactistics of solids using the basic definition of matter. 
27:22 – 32:19 Teacher: Fine besithe gas is everywhere anditsho? Kukho ntoni apha(inside the syringe? Ndiwakhuphile amanzi?Kukho ntoni apha ngoku? Class: Gas Teacher:Kukho igas neh? Andizubuza uba which gas but ndizawthi masiphinde senze the same thing and compare the compressibility between gases and liquids. Uvale uqiniseke uba uvalile. Uwakhuphile amanzi? (class answer yes) Teacher: Uqiniseke amanzi uwakhuphile and then uvale and then you push?kuyenzeka neh? Class: Yess Teacher: Kokuphi okulula in gases and liquids? Kokuphi okulula in gases and liquids? Class: Gas	**Comment:** The focus of this discussion was to compare compressibility between liquids and gases using a demonstration. **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** Tehe teacher asked learners to bring gas syringes she brought to the class and instructed them to draw water using the syringes, she then told learners to use their index fingers to close the knozzle, therafter she instructed learners to try and push water out of the syringe. She then instructed learners to empty the syringes and then told the learners that the empty syringes had gas inside. Learners then perfomed the same experiment using the gas. The teacher then asked which one was easier to push between gas and liquid.

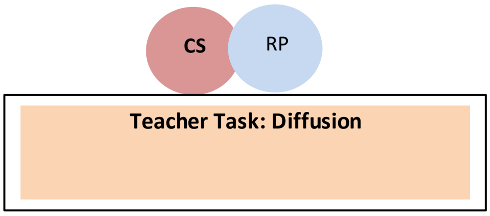
Teacher: Huh? Yi-gas so you are saying gas is easily (compressible). Hayi suka besithe masibayeke o press no push. Kulula ukuyicinezela yona igas nhe compared to liquids. iLiquids zona uvele usebebenzise amandla zona zisuka, awayi ndawo la manzi lawa ahamba kancinci eme andithi? Yintoi enye xa sithetha nge Liquid? iSolids kaloku zona ngoku, le desika xa uyicinezela uzakuyicinezela iyephi? Uyakwazi, uyakwazi uyicinezela itshone? Iyephi kaloku? Ndiwagqibile amandla am ngoku. So isolids zona so are not compressible anditsho? Hayi ke niyekile ke ngoku, nivukwe likakade, niyeke tu ngoku.	Learners' Response: Learners responded that it was easier to push gases than liquids. Teacher Noreen's Action: Teacher Noreen then confirmed that indeed it was easier to push gas because gases are easily compressible than liquids. The teacher further told learners that solids were not compressible and made an example using a class desk. In the teaching segment above, teacher Noreen is using her knowledge of representation (RP) to confirm teach concept of compressibility in liquids and gases (CS). 
32:19 – 35:00 Alright ndicela sijonge (sends a learner for a matches) Ndicela ke ngoku khe sijonge into yoba, sijonge pha, sijonge phaya kwi Solids kuqala, ziphi iSolids zam? Nazi, pha kwi Solids sibone into yoba ikhona into esinoyenza ukwenzela uba iSolids zitshintshe mhlawumbi zibe yenye iphase. Sithe kaloku we have three phases of matter andithi? Sathi phases zethu zeziphi, zibize? Phases of matter, xasidibene hands up? Phases of matter? Anisafuni nophakamisa now? Senifuna uthetha qha ngoku? Zibizeni ke! Class: Solids, Liquids, Gas Teacher: Solids, Liquids, Gas, Teacher: siyakwazi ngoku ukuthetha okanye ikhona indlela esinokwenza ngayo, anything that we can do so that kungantshintsha iSolid to one of two phases? Huh? Ude wabona sitsinthsa iphase(Changes of phase)uqaphele lonto?(class reply yes) Sifuna ujonga iSolid le singakwazi uyitshintsha mhlawumbi ibeyi gas or ibeyi Liquid? Class: (mumbling) [yi solid Mem) Teacher: hayini bethuna Nosele niyixoxe niyixoxe nodwa nide niyizise kum, ndiyayithanda into ephuma kwaba bantu kuba bazimisele (pointing one group). Ungathethi nam khothi ndibaleke(running away from one group). Class: Solid change to be liquid Teacher: Solid change to be liquid, kanjani? How? Class: Ice melting	No TS
Lesson 2	
0 – 2 min Teacher: Hands up, hands up? Thank you, oright Uphi umatches wam? As much as kukho ezi zinto ziphambi kwakho andithi, ndicela ube careful about zona, ispirit siyatshisa moos niyasazi. Ingakhe ilinge ibengathi siyachitheka uyeva? Ndicela uni light-ela ngokwam. (Teacher lighting the experiment primas/ stoves). Grade 8s? Grade 8 Class: Mem Teacher: Ubuthe Solid change into liquid, so wathi ice can change? Class: Yes Mem Teacher: Ndabuza kanjani, yathini impendulo yakho? Huh,	No TSPCK Episode

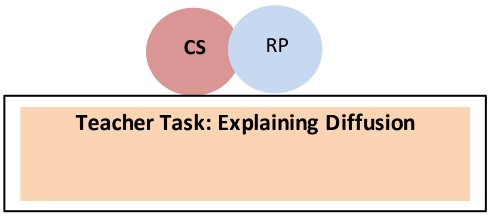
[demonstration]	
2 min – 8:14 min Teacher: Huh, how does it change guys? (class mumbling) – (teacher distributing ice on each group on the cylinder and start melting). Kwenzekani? Class: Iyanyibilika [IT IS MELTING] Teacher: Iyanyibilika Class: Yes Teacher: Iyanyibilika besithe, besithe neh a solid andithi, sathi a solid can change to liquid andithi? We took ice. I-Ice yakho you are saying iyathini? Kuthini unyibilika kanene? Class:Melting Teacher: Ice yakho is melting andithi? Teacher: Now iye isiba ngamanzi, suba excited Grade8 uyeva thethela phantsi kwenzele nam ndivakale ndithini uyeva? Kuyavutha kuyanyibilika (teacher going around the groups) Teacher: Alright by melting – kula Solid yintoni ebangela ku melte kanene? Yintoni ebangela ku melt-e. Class: Heat Teacher: because of heat andithi? Alright besithe particles in solids are closely added together andithi?zixinene zenze igaqa andithi? Noba limile kanjani andithi? Now by adding heat to that solid it is now melting.	**Comment:** The focus of this discussion was on phase change **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** The teacher asked learners how do solids change to liquids. The teacher then distributed ice to students and set alight the mini burners she brought to class and learners used these to heat ice. The teacher then asked how does ice change from solid to liquids. Learners' Response: Learners responded that the solids changes to liquids by melting Teacher Noreen's Action: Teacher Noreen then confirmed this knowledge and then asked the reason fro melting and student responded that it was because of heat. In the teaching segment above, teacher Noreen is using her knowledge of representation (RP) to confirm teach phase change from solding to liquids (CS). 
8:14 – 11:25 The particles in solids were closely packed together and what about the particle ke ngoku in water, particles in water? They are……? Loosely packed? Andithi? Class: yes Miss Teacher: They are not closer andithi azixinenanga njengakwi Solids zona andithi Class: Yes Miss Teacher: Fine, amanzi akho ke ngoku are getting hotter I am hoping so Learners: Sezobila Teacher: Taking rounds to see the demonstration in students desks Teacher: Grade 8 ndifuna sijonge I wonder uba {not clear} ndicela sijonge nhe as we see that iIce yethu has melted all together we do not have ice now anymore andithi, we have water andithi, at the bottom of what you have used as your pot, there are particles, anditsho Class: Yes Teacher: Eza particles, are they moving? Zijonge, are they moving? Class: Mummbing Teacher: Jongani kaloku are your particles moving or not	No TSPCK Episode

<table>
<tr><td>
Claas: Yess
Teacher: Moving?
Class: Yes
Teacher: Okay, ndifuna sijonge the movement of particles, are they moving
Class: Yes
Teacher: Are they fast or slow
Class: Slow
Teacher: Ziyamova
Class: Yes
Teacher: Zi slow or are they fast
Class Slow
Teacher: They are slow
Learners: Yes</td><td></td></tr>
<tr><td>11:25 – 14:08
Teacher: what else is happening, ngaphandle kwe particles ezi uzibonayo emanzini yintonin enye eyenzekayo
Class: Yi water vapour
Teacher: Yi water vapour
Class: Yes
Teacher: Okay you are saying there is water vapour nhe
Class: Yes
Teacher: Khawubeke isanda sakho and see what is going to happen

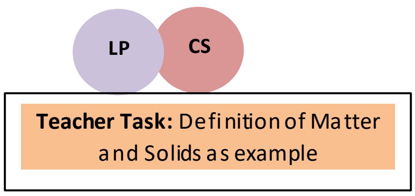
Teacher: Ubeke isandla sakho and see kuzokwenzekantonina
Teacher: Kwenzekantoni (pointing a student in one of the groups)
Learner: Siyabila
Teacher: Siyabila? Kwenzekantoni (going aroun different groups asking kwenzekantoni)
Teacher: (Coming to back to the first group she asked to place hand over the little heating water) kwenzeke ntoni
Learners: siye sabila Miss
Teacher: Xa sibila sinantoni
Leaners: Sinamanzi</td><td>No TSPCK Episode</td></tr>
</table>

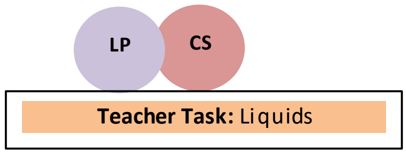
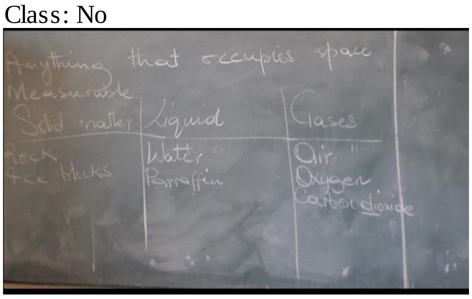
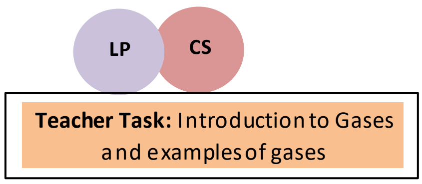
Teacher: Phase change itshintsile iIce ebikwi solid because of heat yayi liquid andithi,	
14:08 – 16:08 Teacher: Phase change itshintsile iIce ebikwi solid because of heat yayi liquid andithi, uthi ke ngoku wena pha isolids ziyakwazi utshintsha zibezi liquids anhe, Class: Yes Teacher : khandimamele kaloku suzoxa nayo kakhulu, zibe ziliquids andithi and then uthi there is water vapour there andithi Class: Yes Teacher: Water vapour yintoni kanene Class: steam Teacher: Sithe yi liquid or solid Learners: Gas Teacher: Oh it is a gas andithi Class: Yes Teacher: Now ithini ke ngoku yintoni onoyithetha about ichange of phase, okwakutshintsha kwala Solid phase to liquid yintoni enye into onoyongeza pha eyenzekileyo uthethe ngomophu lo uwubonayo, yes sisi, Elam? Learner: Liquids can change to gases Teacher: Uth uElam as much as uba sisithi solids can change to liquid neliquids can change to gas anditsho, Class: Yes	No TSPCK Episode
16:08 – 20:26min Teacher: Yonke lonto yenzeka because of what? Class: Heat Teacher: Because of heat andithi Class: Yes Teacher: Siyayingqina sonke lonto Class: Yes Teacher: Okay eeeeeeeh ndirhalela, masicimeni iburners ezi ungatshi, yeka ndizicime ngokwam, oright, sine test tubes sonke andithi sine test tubes sonke Class: Yes Teacher: you are getting out of control ngoku you are excited andiyazi uba kwenzeka ntoni inye qha igroup engekho excited ndicela apha ke sibonile mos uba isolids zethu ziyakwazi utshintsha zibeziliquids from being a liquid to? Class: Solid Teacher: Huuuuh? Class: to a gas Teacher: To a gas tyhini wandiqhatha ngoku, ndifuna sifake le isolid , net nje uba ndiyifake ndifuna undixelele uba yintoni le ndiyigaleleyo apha [teacher adding some substance in the test tubes that had water inside for all groups in the classroom) uzakundixelela ukuba yintoni le ndiyigaleleyo Teacher: Grade 8 Grade 8 yintoni le esiyigaleleyo Class: SiSpirit CLASS: YI COOL AID Teacher: NIYAKUTHANDA GQITHI UKUTYA , inoba uAyaBONGA yena uhlala noMakhulu lento eyazi uba nguzifo zonke cLASS: lAUGHING AND SOME STUDENTS SAYING YESSS	No TSPCK Episode

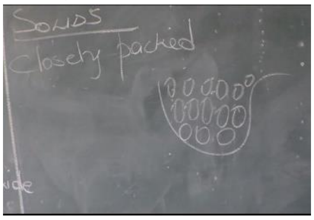
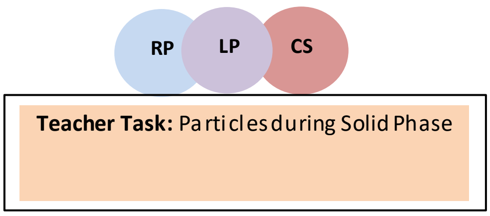
tEACHER: Nina bantu abangenabo omakhulu, you cant even see uba nguzifo zonke lo, oright uthi nguzifo zonke nhe Class: Yes Group A: A certain group called teacher to check their test tube and the teacher went to check it Teacher: Hayini bethunani Grade 8 quiet quiet niyayazi uba yintona le ingxolisayo kula group kuthwa pha mna ndigalele ispirit, sikhona iSpirit esiligaqa?	
<u>20:26 – 23:32 min</u> Class: NO Teacher: Grade 8 Class: Miss Teacher: Grade 8, nguzifo zonke lona simgalele apha siyevana but there is a scientific term for uzifo zonke apha esikolweni asinaye uzifo zonke sinantoni sinantoni huh? [writing on the blackboard: Potassium] liphelele elagama? Huh? Liphelele [teacher continues to complete the term: Permanganate] Teacher: Potassium Permanganate crystals asinayo into engu zifozonke aph' eskolweni siyevana Class: Yes Teacher: Yithathe ke itest tube yakho, le ugelele kuyo nhe uyishukumise [demonstrating to learners by shaking her solution of water and potassium permanganate], uyayibona nhe Class: Yes Teacher: Yintoni le yenzeke pha, [shaking the test tube further] yintoni le yenzeke pha [teacher writing on the BB – Diffusion] Grade 8 grade 8 Grade 8 Class: Miss Teacher: yi Diffusion, andithi ugalele kaloku phaya your Potassium Permanganate, yafika yayohlala phaya ezantsi, uyibonile? xa ihlala phaya ezantsi andisayirhaleli enye itest tube so that ndifuna umntu abone uba kwenekeni because what I have notices is that you are getting excited, Andisa, awujonganga ncam ncam ncam andiyazi ndizothi nijonge kanjani but anisajonganga ncam ngalendlela bendifuna nijonge ngayo Teacher: ndiphethe itses tube ke mnake ndifuna umntu ajonge [starting the demonstration again with clean water ina test tube and soild potassium permanganate;] ihleli pha ifika ingenapha ithi dyump yahlala ngoku izama uku speada uyayibona	**Comment:** The focus of this discussion was to discuss introduce the concept of diffusion **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** The teacher asked to use potassium permanganate and test tubes she brought to class. The test tubes were half-filled with water learners and learners were instructed to add in potassium permanganate in water and observe. Teacher then asked what was happening Learners' Response: Learners kept quiet Teacher Noreen's Action: Teacher Noreen told learners that what was happening was diffusion. In the teaching segment above, teacher Noreen is using her knowledge of representation (RP) to introduce learners to the concept of diffusion. 
<u>23:32 – 25:52 min</u> and then now mamela mamela ifike yahlala apha andithi amanzi ese clearn andithi? Class: Yes Teacher: yanyibilika yazama ukugqiba yonke indawo aye ejika lamanzi they become stronger and stronger andithi? Class: Yes Teacher: Ade abe ayafana onke andithi, andithi Learner: Yes Techer: Yilento sithi ke ngoku yintoni leyo, [pointing at the word Diffusion on the BB] Diffusion, ndicela ke ngoku one person okanye umntu kwi group ne group asixelele uba what is diffusion? Ungathi yintoni idiffusion inn your own words? I am giving you one minute , undixelele uba what is diffusion, in your own words? Yintoni idiffusion,	No TSPCK Episode

niphakamise isandla if seninayo iexplanation, what is diffusion Grade 8, Mamela Grade 8 kuthwa Grade 8	
25:52 – 28:38 min Xa iye ithi idibana yonke, iye iyeke uba strong-o kanje ngalapha (holding a glass tube) ngelexesha ubusando kuyigalela andithi? Class: Yes Teacher: So ndithi ke ngoku idiffusion it is a movement of particles from the region of higher concentration to the region of lower concentration. Xa ufaka ispray okanye kukho into enukayo ephuma kula corner usifake pha esa spray sinuke side sibatsarhe andithi? Bakhuze abaya (pointing another group) bathi yhu asisanuki kakubi okanye kamnandi andithi? But abaya phaya bazakuva ngaphantsi kwaba (pointing a distance group). Liya lincipha moos ela vumba lisuka phaya liye licipha lincipha lide ligqibe indlu le yonke and alisanuki ngolwahlobo belinuka ngayo ngokuya kuqala phaya(pointing an area where the spray besifakwe khona)andithi? Class: Yes Teacher: Yi diffusion yokuba concern yethu was with changes of matter andithi? Sithe kaloku besigalele iSolid apha andithi? (class answer yes) Yatshintsha yanyibilika yonke yaba ngamanzi, niyayibona? Alright can you please light our burners once more? Yibeke ibeaker yakho Ucinga uba kuzokwenzeka ntoni ? What do you think will happen? Huh? Nisayixoxa (class mumbling) huh? Nisayixoxa? Yes sisi Learner: It will become a solid. Teacher: Niyamva? (class answer yes) uthini?It will become a solid again andithi? Which means as much as ba when you add liquid, solids they become liquids andithi ….when you remove the…………	**Comment:** The focus of this discussion was to discuss further the concept of diffusion **<u>In-depth Qualitative analysis:</u>** **Teacher Noreen's Role:** The teacher then explained that as potassium permanganate was added into water, it first settled at the bottom of the test tube then tried to spread out into the entire tube. The teacher then explained that when potassium permanganate was added into the tube, it was more concentrated at the bottom of the tube. The teacher explained that this was because *"difussion is the movement of particles from the region of higher concentration to the region of lower concentration"*. Teacher Noreen further made another analogy with a spray and explained to learners diffusion was the reason that when you spray from one corner of the room after few minutes the scent of the spray would start to spead out until everyone in class could smell it In the teaching segment above, teacher Noreen is using her knowledge of representation (RP) to teach learners the concept of diffusion and how it happens (CS). 

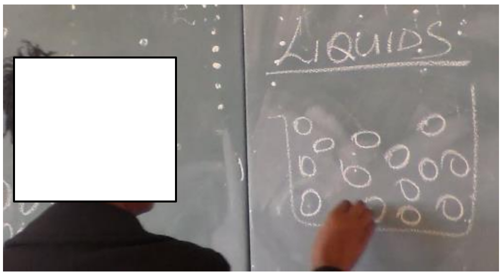
APPENDIX 18: Analysis of teacher Noreen's enacted post-intervention lesson

Lesson 1	
0– 3 min Miss: Good morning everyone Class: Good morning Miss Miss: Sisodwa ngok akhomntu. Do you remember anything about matter? Class: mumbles Miss: two different things, what is matter hands up? (teacher writing matter on the board). What is matter guys? Phakamisa isandla, hands up Class: (child stands up) Matter is anything that occupies space. Miss: Again Class: Matter is anything that occupies space. Miss: what else can you say? Class: It is measurable Miss: It is measurable Class: yes miss Miss: khanindiphe the examples of matter. It occupies space, it is measurable, any examples? Class: Solid Miss Miss: Solid matter. Caba zikhona imatter eziyiSolid, like what? (writing solid matter on the black board) Zithini iexamples of Solids. Anifuni nondijonga Sesethu, thetha Sesethu. Class: Rock. Ice blocks (writing on the board) Miss: uthe Rock Yintoni irock? Ice blocks. Oright Solid matter, ziexample zesolids eziya	<u>**Comment:**</u> The focus of this discussion was introducing matter and the three states of matter <u>**In-depth Qualitative Analysis**</u>: **Teacher Noreen's action**: teacher prompted into learners' thinking about matter and asked what matter is? **Learner's role**: Learner responded that "*Matter is anything that occupies space*" and also added that *"it is measurable"* which made teacher Noreen aware of knowledge that learners had (LP) **Teacher Noreen's action:** teacher then asked learners to give examples of matter **Learners' Role:** The learner said solids were examples of matter and the teacher further probed for examples of solids and learners gave examples and teacher Noreen noted these on the blackboard. In this classroom action, teacher used TSPCK components of LP and CS in an interwoven manner (LP/CS) to teach the concept of matter and its examples A TSPCK Map for this teacher action is given below: 
3 – 5 min Nantoni enye? Zisolids nantoni? Yes! Class: Liquids Miss: we are talking about these three states of matter ukuba sihamba sonke kakuhle. Kaloku siyazohlula ngok andithi? Class: Yes Miss: Solids, Liquids zeziphi esingekazibizi? Class: Gases Miss: Gases. What is the difference between istates of matter. Yintoni umahluko. Sithe isolids, irock is an example of isolids, and ice blocks. If singajonga kwiLiquids, masiqale nge examples zeliquids mhlawumbi. Mhlawumbi sizokwazi ukuphendula. Yes	<u>**Comment:**</u> The focus of this discussion was on liquids and its examples <u>**In-depth Qualitative Analysis**</u>: **Teacher Noreen's action**: the teacher reminded learners that the discusiion was about the three states of matter and instructed learners to give her another state of matter like they did with solids. **Learner's role**: Learner responded that another state of matter was liquid state **(LP).** **Teacher Noreen's action:** Learners were instructed to first give examples of liquids before stating the difference between the states of matter **Learners' Role:** Learners gave examples of liquids and teacher Noreen noted these on the blackboard. In this classroom action, teacher used TSPCK components of LP and CS in an interwoven manner (LP/CS) to introduce liquids as another form of matter

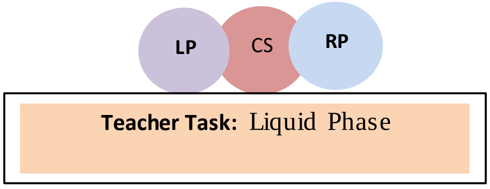
 Class: water Miss: WHAT ELSE, YES? Class: Parafin teacher: writing ON THE BLACKBOARD [PARRAFIN]	with its accompanying examples. A TSPCK Map for this teacher action is given below: 
4: 55 – 06: 52 min Miss: ungandipha iexample of, iexamples of gases? Class: Air Miss: Air, what else? Class: Oxygen Miss: okay, iexample of gases nithe Air, andithi, ngeyiphi enye? Class: Yes Miss Miss: Hayini bethunana, kutheni kungasathethwa, kwenzekeni? Niyoyika? Thethanike, ngeyiphi enye iexample. [WRITING OXYGEN] Yintoni ioxygen, hii? Yintoni ioxygen? Class: Yigas Miss: Ngeyiphi enye iglass eniyaziyo? Class: Carbon dioxide Miss: Carbon dioxide. What do you mean when you say Di? Zingaphi? Class: 2 Miss: oh, alright. Masijongeni ngok uba sinesolids, sineliquids, sinegases andithi? Class: Yes Miss. Miss: Uyayiqhaphela uba isolids ziyaphatheka? Iyaphatheka, Class: Yes Miss: iliquids ziyaphatheka? Class: No Miss: Ziyabonakala? Class: Yes Miss: Igases ziyabonakala? Class: No  Miss: Liquids, ziyabonakala Class: Yes Miss: igases ziyaphatheka? Class: No Miss: Ziyabonakala? Class: No	**<u>Comment:</u>** The focus of this discussion was introducing learners to gases as another form of matter and exampls of gases **<u>In-depth Qualitative Analysis</u>**: **Teacher Noreen's action**: teacher prompted into learners' thinking about matter and asked what matter is? **Learner's role**: Learner responded that "*Matter is anything that occupies space*" and also added that *"it is measurable"* which made teacher Noreen aware of knowledge that learners had (LP) **Teacher Noreen's action:** teacher then asked learners to give examples of matter **Learners' Role:** The learner said solids were examples of matter and the teacher further probed for examples of solids and learners gave examples and teacher Noreen noted these on the blackboard. In this classroom action, teacher used TSPCK components of LP and CS in an interwoven manner (LP/CS) to teach the concept of matter and its examples A TSPCK Map for this teacher action is given below: 

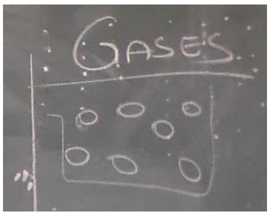
06:52 – 09: 17 min Miss: okay, let us go to properties, sohlule. Properties of solids? What are the properties of solids? Zintoni ezi ezibangela uthisawujonga eqonde uba uthi yisolid lena? Class: particles are closely packed in an orderly manner. Miss: particles are closely packed together in an orderly manner. Is that correct? Uthini uNombulelo? Class: particles are closely packed together in an orderly manner Miss: Closely packed nhe. Ndifuna ukuzipakisha pha (teacher drawing on the board glass jar with particles) In an orderly manner. Are they closely packed? Class: No Miss: So ndiwrongo mna? Class: Yes  Miss: Ndicela undenza undenzele uclosely packed mhlobo wam. Ndicela uzenze zibe closely packed in an orderly manner. Kuthiwa ziwrongo ezam, gqhibezela, uzokutsho when you are ready. (Student drawing on the black board)  Ndiyisuse lena yam, iright lena yakhe? Class: yes Miss Miss: Closely packed together in an orderly manner.	**Comment**: In this teaching segment the teacher is introducing the learners to the concept of particle concept underlying solid form of matter **Teacher Noreen's Role:** The teacher instructed learners to now look into properties of solids and asked learners what were the key diffrences dinstinct to solid matter. **Learner's Role:** The learner responded, "*particles are closely packed in an orderly manner"* **(LP***)* **Teacher Noreen's Role:** The teacher then confirmed this knowledge by drawing a glass beaker on the blackboard representing particles in solid phase and deliberately made spaces between particles and later asked learners if the representation was correct and whether particles were closely packed enough **(RP).** **Learners' Role:** The learners responded that the representation did not represent particles that were close enough and one student went to the blackboard to add more particles in the glass beaker to make particles close packed together. **Teacher Noreen' Role:** Teacher Noreen emphasised throughout this discussion by repeating that particles in solids were closely packed together **(CS).** As compared to the lessons prior the intervention, teacher Noreen's explanation are quickly directed to particle nature of matter rather than only explaining concepts from macroscopic level. The teacher started by moving from the macroscopic processes she gave in the previous segments into sub-microscopic explanations using representations to demonstrate particle arrangement during solid phase (RP) The sequence of the components RP/LP/CS in the TSPCK episode above can be mapped as follows: 
09: 17 – 10:49 min All right, maseske sijonga neLiquids in terms of arrangement (mumbling). Zinjani zona illiquid particles? Are the closely packed together nazo? Class: No Miss: hands up ke umntu andiphendule hay andizothetha nomntu yi one mna bebaninzi kangaka abantu apha kule Class, yes bhuti, Sima ufuna ukuthini Student: Particles are loosely packed in a disorderly form Teacher: Unyanisile? Kutheni abanye abantu bengafuni kuthetha nje mmmmh sit down Sima enkosi…okay (drawing a picture of particle	**Comment:** In this teaching segment the focus was on particle arragangement in Liquid Phase **Teacher Noreen's Role:** The teacher then continued to now talk about Liquid phase as she asked learners the arrangement of particles in liquid phase **Learners' Role:** Learners responded that particles were loosely packed in liquids **(LP)** **Teacher Amanda's Role:** The teacher confirmed this learner prior knowledge using her knowledge of curricular saliency **(CS)** to draw up a corresponding representation **(RP)** which represented arrangement of particles in liquids. In the TSPCK episode above, the teacher is using knowledge of LP/CS/RP interactively to take learners

<table>
<tr>
<td>arrangement during liquid phase)……ziryt?
(pointing at the diagram)



Class: Yes
Teacher: Zahlukile ezi kwezi?
Class: No
Teacher: Huh
Class: Yes
Teacher: (Teacher re-visits particle of solid and filling up the student drawing with more particles while emphasing that Closely packed in a orderly manner?</td>
<td>through particle explanations in Liquid phase The resulting TSPCK Map for the above discussed episode is given as follows:


</td>
</tr>
<tr>
<td>10:49 – 12:52 min
Alright masiphinde kqala sijonge I arrangement ye gases (writing on the blackboard – Gases) zitheni zona igases? Heeee animathanga, niqumbeleni kodwa
Class: Mummbling
Teacher: Naske nalulama kangaka, huuh…how are the…arrangement of gas particles. Huuuh…yes Ngqali
Student: Uxolo Miss there is no arrangement
Teacher: Otherwise they are closely packed
Student: No Miss
Teacher: Akhomntu uthetha enye into? Akhomntu ufuna uthetha enye into, Tshewu? Mmmm? Akhonto ingenye ofuna uyithetha? Heee hayi nindixakile namhlnje? Mhhhhm? Akhomntu ufuna uthetha? Yes sisi?
Student: Uxolo Miss they are loosely packed and they have no particular arrangement
Teacher: The gas particles?
Student: Yes Miss
Teacher: (Drawing a diagram)



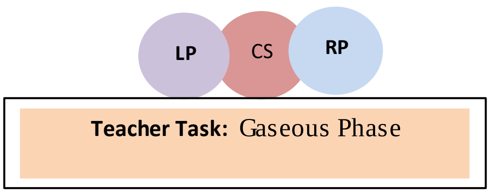
They are loosely packed okay…iyafana lanto siyenze pha?
Class: No
Teacher: Iright le ndiyenze pha (meaning the drawing of gas particles she drew)
Class: Yes
Teacher: Le na le (referring to the liquid and gas particle diagrams on BB)</td>
<td>Comment: In this teaching segment the focus was on the particles in gaseous phase

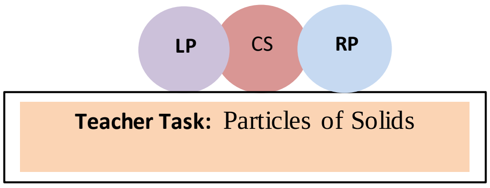
Teacher Noreen's Role: The teacher instructed learners to focus on gases particularly the arrangement
Learners' Role: Learners responded that particles had no arrangment (LP)
Teacher Noreen's Role: The teacher had a follow up question to learners as she asked if that meant particles were closely packed and thereby channening learner thinking into inclusion of order of particles in gas phase.

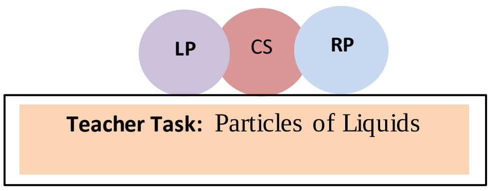
Learner Response: The learner resonded with a No and one student stood up with the following response "Uxolo Miss [a xhosa word meaning excuse me teacher] they are loosely packed and they have no particular arrangement".

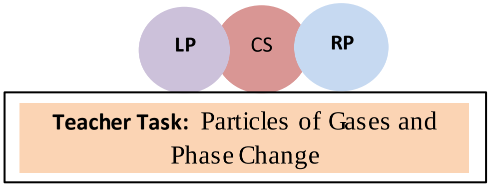
Teacher Noreen's Role: The teacher completed the learner response by repeating that gas particles are what they were talking about (CS). The teacher then confirmed this concept by drawing its corresponding diagram on the blackboard to represent particle arrangement of gases (RP).

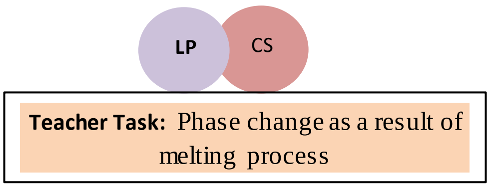
In the TSPCK episode above, the teacher is using knowledge of LP/CS/RP interactively to take learners through particle explanations in gaseous phase The resulting TSPCK Map for the above discussed episode is given as follows:

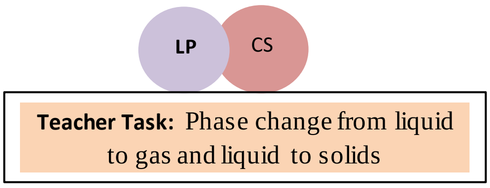

</td>
</tr>
</table>

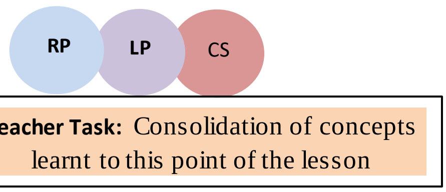
12:52 – 15:55 min yeyiphi enye into esinothetha ngayo besides arrangement Class: Spaces Teacher: Spaces between particles Class: Yes Teacher: Ungathini about ispace between particles phaya kwi Solids, ufuna ukuthi sitheni ispace between iparticles, yes Sima Sima: In solids spaces between particles are very small, smaller than in liquids and gases Miss Teacher: Spaces between particles are very small okay…..eeehhhh what about the movement of particles, what about the movement of particles, yes (student xx). Student: They do not move but vibrate Teacher: Sithetha ngeyiphi kengoku, nge gases?ngeSolids? ngeliquids? Student: Solids Teacher: Solids they do not move but they vibrate Student: Yes Miss Teacher: Okay……xa zingazomova zizo vibrator nje, anidthi xa ivibrator iyagungqa nje ayiyindawo Student: Yes Miss Teacher: (Pointing at the diagram drawn by student on solids) ezi sinazo apha ispaces akunakubakho movement pha huh? Class: Ingakhona Miss Teacher: Which means la arrangement yethu ayokho right andithi? Class: Yes Teacher: (Filling up the gaps and big spaces in the drawing of solids on BB) Alright so that they do not move they vibrate, very small spaces between particles, yhoooo aniqumbanga ndindiqumbele na? (Class responding: NO) qha kutheni babethunani? Andinithandi tuu huuuh okanye nini aninidithandi? (Class responded: No Miss) Teacher: Fine, niyayibona ke ngoku into yokuba xa siisthi they are closely packed together we mean that there are no spaces, there are very small spaces between them in so much that they cannot move only vibrate, andithi? Class: Yes Teacher: At least ngoku inoba it makes sense sizijongile pha because nathi sijongile nje akho ndawo yohamba ngoku pha (showing a diagram on BB with very packed particles) Andithi zingagungqa kodwa azinakuya ndawo andithi? Class: Yes	**Comment:** In this teaching segment, the focus was on the concept difference in spaces between particles in the three phases of matter. **Teacher Noreen's Role:** The teacher turned focus to concepts of spaces between particles and asked learners what they knew about spaces between particles in solids? **Learner's Role:** Learner XB responded that there were very small spaces between particles specifically smaller than in liquids and gases **(LP)** **Teacher Noreen's Role:** The teacher confirmed the student response and further asked the movement of particles? **Learner's Role:** Learner XC responded that particles in solids do not move but vibrate **(LP)** **Teacher Noreen's Role:** The teacher reapeted what student XC said and further explained that by vibrating that meant the particles in solids only vibrate in fixed positions (CS). The teacher then pointed learners to the glass beaker she drew on the blackboard and asked if the representation was correct as it still had some bigger spaces (RP) and corrected the diagram to fit the explanation which the learners gave to particles of solids 
15:55 – 18: 09 Masiye kwi arrangement of partciles in liquid, I mean i movment, sithini ke pha? Arrangement of particles I mean movement mmmmh zimova kanjani zona? Zinga kwazi ukumova ngokukhawuleza ngalandlela zenziwe ngayo pha? Huh? Class: No Teacher: Huh? Zingakwazi ukumova kqla nje? [class responded: Yes Miss] Teacher: Zinaso ispaces? Class: Yes Miss	**Comment:** In this teaching segment, the focus was on the concept of spaces between particles in liquid state. **Teacher Noreen's Role:** The teacher turned focus to concepts of spaces between particles of liquids and asked learners what they knew about spaces between particles and movement of particles in liquids? The teacher used the diagram she drew on the blackboard if these particles can move fast at all with the way they are arranged.

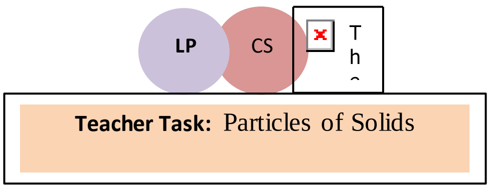
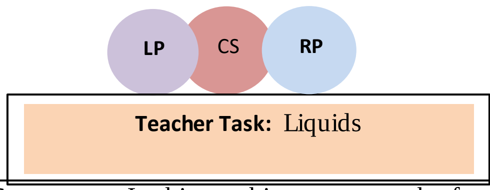
Teacher: And then phaya kwi liquids, the spaces are small but no as in solids andithi? Class: Yes Miss Teacher: And then phaya kwiliquids, the spaces are small but no as in solids andithi? Class: Yes Miss Teacher: But Still ispace between the particles of liquids are not as big as spaces between gases, andithi? Andithi amanzi xa eeee xa uwaphekile ayabashushu ne xa ebila enza kanjani? Class: ayaxhumaxhuma Teacher: Ayaxhumaxhuma Class: Yes Miss Teacher: Athini xa exhumaxhuma, ayacotha? Ayakhawuleza? Class: Ayakhawuleza Teacher: So ayamova andithi? So unlike iSolids Because nalapha idesika le zi particles ezenze idesika but awuboni kwa oko vibrator andithi? Class: Yes Miss Teacher: Its like ihleli awuboni kwa ezo particles zixineneyo nandithi? They are closer together andithi?	**Learners' Response** : the class responded with a NO **Teacher Noreen's Role:** The teachers and further asked asked if there were any space between the particles of liquids and she used the diagram representing particles of liquids which was on the blackboard. **Learners' Role:** Learners responded with a Yes **Teacher Noreen's Role:** The teacher confirmed the student response and further consolidated the discussion by telling learners that the spaces between liquids were small but not as small as in solids. The teacher added that the space between particle were not as big as in gases In the TSPCK episode above, the teacher is using knowledge of LP/CS/RP interactively to teach learners about particles of matter in liquid state. The resulting TSPCK Map for the above discussed episode is given as follows: 
18:09 – 20:21min Alright and then ke ngoku kwigases ke ngoku, ispaces in between particles Class: Mummbling Teacher: Huh? Ndisabela lento ithethwayo, ispaces ke ngoku are bigger andithi? Class: Yes Teacher: So zona ziyakwazi ukuhamba hamba nakanjani uyabona mos umoya uvuthuza uvuthuze ubheke ngapha nangapha andithi? Class; Yes Miss Teacher: Grade 8 siyevana? Class: Yes Teacher: Siyevana nhe? Alright abanye abandijonganga kodwa ke bathi bayandiva…Masiye kwi phase change kengoku xa sithetha nge phase change sithetha ngokutshintsha andithi (writing phase change on BB) xa ujongile wena pha kwezi phase zintathu sithetha ngazo sithethe ngeSolids sathetha nge liquids sathetha nge gases andithi, yeyiphi ekwaziyo utshintsha iye kwenye? Class: Solid Teacher: Solids Class: Yes Teacher: Ziyakwazi iutshintsha? Class: yes Teacher: Khawundenzele umzekelo wotshintsha kwe solids (writing soilds on BB) khawundenzele umzekelo wotshintsha kwiSolids, Mkupha? Student: Change to liquid Teacher: You put ice….. Student: On a heat Miss, it can change to liquid	**Comment:** In this teaching segment, the focus was on the spaces between particles between gases and introducing phase change **Teacher Noreen's Role:** The teacher turned focus to concepts of spaces between particles of gases using the digram of representations of gas particles on the blackboard **(RP)** and told learners that the spaces between particles of gases were bigger and could move very fast in any direction **(CS).** The teacher then asked learners to now look at the phase change and aksed them between the three states of matter, which they discussed which one could change to another form. Learner's Response: Learner XD responded that solids could change to liquids **(LP)** Teacher Noreen's Role: The teacher told learners that if you put ice… **Learners' Response** : Learner XD finished this statement by stating that the class responded with a NO **Teacher Noreen's Role:** The teachers and further asked asked if there were any space between the particles of liquids and she used the diagram representing particles of liquids which was on the blackboard. **Learners' Role:** Learners completed the teacher's response *"On a heat Miss, it can change to liquid"* In the TSPCK episode above, the teacher is using knowledge of LP/CS/RP interactively to teach

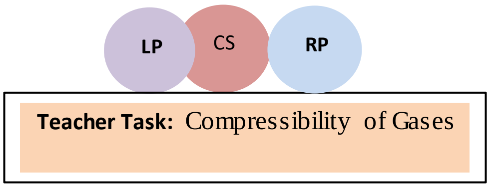
<table>
<tr><td>Teacher: Changes to liquid?
Student: Yes Miss
Tecaher: Siyamngqinela, is that true?
Class: Yes</td><td>learners about particles of matter in gas phase and phase change. The resulting TSPCK Map for the above discussed episode is given as follows:

</td></tr>
<tr><td>Lesson 2</td><td></td></tr>
<tr><td>0 – 2 min
Teacher: Okay, yintoni la process eyenzeka pha?
Class: Mumbles
Teacher: Huh
Class: Melting
Teacher: Xa inyibilika
Class;Yes
Teacher: Iyamelta nhe…. (class responded : Yes) okay iSolids can change to liquids by melting, yeyiphi enye iphase okwazi ukuyithsintsha from one state to another state?mmmmh yeyiphi enye ekwazi utshintsha….okay……masibuyele umva siye pha kwi Solids besine examples of solids andithi> IRock iyakwazi utshintsha?
Class: No
Teacher: iIce iyakwazi utshintsha?
Class: yes Miss
Teacher: ebesetshilo uAthini wathi Ice when heated it melts andithi? Masiye ke ngoku kwi Liquids, sijonge amanzi, amanzi ayakwazi utshintsha , [Class: Yes] Xa kutheni?
Class: Mummbles
Teacher: Mandive umntu abamnye, andizoniva xa nithatha nonke….ohh nona into eningayifuniyo kuthetha nhe? Kutheni Aya? Ningafun'uthetha thethani?</td><td>Comment: In this teaching segment, the focus was on physical processes involved in particles to change from solids to liquids
Teacher Noreen's Role: The teacher asked learners the process that occurs when solids change phase to liquid.
Learner's Role: Class responded that it was melting (LP)
Teacher Noreen's Role: The teacher confirmed the student response repeating that solids can change to liquids by melting (CS).

In the teaching segment above two TSPCK components were used and these were LP/CS. The resulting TSPCK Map for the above discussed episode is given as follows

</td></tr>
<tr><td>02:00 – 6:27 min
Kutheni Ningafun'uthetha ngoba kaloku ngoku niphendulayo bakhona abantu abahendulayo but ngoku xa kufuneka kuthethe umntu akaveli umntu abantu banazo impendulo qha baqondba hake sinawe namhlanje asizothetha kwathina masithetheni bethuna, sithethe nje ibengathi akwenzekanganto, yes Lumka?
Student: xolo Miss when you heat water evaporates and change into water vapour
Teacher: Water Vapour?
Student: Yes Miss
Teacher: So Liquids can change to gases mmm yeyiphi kanene la process? Xa utshintsha liquids into solids oooh yi evaporations nhe [Class responded: Yes] Liquids to gases, can liquids change to solids
Class: Yes
Teacher: Kanjani?
Class: Mummbles</td><td>Comment: In this teaching segment, the focus was on physical processes involved to change matter from liquid phase
Teacher Noreen's Role: The teacher asked what other phase change did they know and went back to the notes on blackboard about examples of solids to ask this question, the teacher the asked if liquids were able to change form and to what form?
Learner's Response: Learner XE responded that 'xolo Miss [a xhosa word meaning excuse me teacher] when you heat water evaporates and change into water vapour'
Teacher Noreen's Role: The teacher confirmed the student response by empasising 'water vapour' and consolidated this response by stating that liquids can change to gases and further asked what was the name of the process that occurs in that case and answered her question stating that when you change liquids to gases the process is called evaporation (CS). The</td></tr>
</table>

Teacher: Hayini bethunani phakamisa isandla mfondini masiyiyekeni lento ye chorus anaswering tshini, hands up Kula khawuthethe mfondini wade wawubopha umlomo wawuval mba, heee Kula kuthethuba wena awuyazi into yoba illiquid amanzi ayakwazi utshintsha abeyisolids Kula: Sorry Miss, illiquid xa uzifake entweni ebandayo nhe iyathsintsha ibeyisolid iqine Teacher: Xa iyi Solid ke ngoku itsho ibeyintoni? Yintoni lo solid uthetha ngayo? Amanzi aqinileyo Luyanda yintoni? Heee nangumhlola yintoni amanzi xa eqinile Kula: Uxolo Miss xa eqinile yi ice block Teacher: Ngoku woyika ukuthi yiIce….okay iLiquids ziyakwazi utshintsha zibeziSolids andithi	teacher further asked if solids were able to change to liquids and learners responded with a Yes and the teacher asked how? **Learner's Role:** Learner XF responded when you put water in a freezer it changes to solid **(LP)** **Teacher Noreen' Role:** The teacher further asked learner XF what was the name of that solid thing after putting in a freezer **Learner's Role:** the teacher responded that the name of the solid was ice block **Teacher Noreen' Role:** The teacher then consolidated the response by stating that indeed liquids can change to solids In the teaching segment above, two TSPCK components were used and these were LP/CS. The resulting TSPCK Map for the above discussed episode is given as follows 
6:27 – 8:30 Teacher: Ngoku woyika ukuthi yiIce….okay iLiquids ziyakwazi utshintsha zibeziSolids andithi yintoni ke ngoku leya iprocess Nkanyi yiSublimation Nkanyie: No its freezing Mam Teacher: Yintoni iSublimation Nkanyie: ku xa zisuka from Solid to gases ku xa zitsiba iphase Teacher: And then masithsise kengoku iplanga, xa uthsisa iplanga lizobayintoni? Class: Mummbles Teacher: Yi Dust? Iplanga mos likhuni? Likhe litshe liphele liphele Class: Others said Yes and others said No Teacher: Hayini yimani libayintoni Class: Mummbles Teacher: Ndivele ndifune umntu ke mnake ngoba kaloku ndivele ndinganiva xa nithetha nonke kwenzekantoni xa utshisa xa ubasa inkuni Class: Mummbles …kuzoqhuma Teacher: Kuqala kuthini? kuqhum nhe? Yintoni la nto iqhumayo Class: Yi Gas	No TSPCK Episode
8:30 – 11:20 Teacher: Okay and then? Nizotshisa ke ngomso nibuye ndindixelele ubhale apha phantsi yonke into eyenzekileyo uyibhale phantsi umntu nomntu akhomntu ungagqithithiyo kwindawo enenkuni sonke silapha, uthathe noba zinkuni ezimbini amantombazana kamnandi azofika abase emakhaya nizofike nibase then nibuye kengoku	**Comment:** In this teaching segment, the teacher is re-vising the concepts of the day and consolidating them unto one discussion or summary **Teacher Noreen's Role:** The teacher asked learners to remind her of all things which they have spoken about during the lesson, and first asked learners what is matter, when learners responded teacher Noreen told learners that in the lesson they also spoke about

Teacher: Alright, sithethe ngantoni kanene namhlanje? Class: Matter Teacher: Sathi what is matter? Class: Matter is anything that occupies space and it is measurable Teacher:and it is measurable, andithi sathi sina 3 phases of matter sithi zintoni, Class: Solid matter, liquid matter, gases matter Teacher: And gases andithi, sathi zintoni iproperties of liquids hand up? Sathi zintoni iprperties ze liquids? Zithini iproperties ze liquids huh? Asemahle Student: Sorry Miss ithi closely packed in a disorderly manner Teacher: Reapiting after student, siright? Class: No Teacher: Sukuthi No qha kaloku, ithi No uphakamise isandla uthethe okanye uthi No ubesowuphakaman uthetha, Pele pele into oyaziyo kuhlea thetha phambi koba uhleke, Properties of Solid, sithe iproperties of Solids Elam? Sudent: The particles are closely packed in an orderly manner Teacher: The particles are closely packed in an orderly manner,	three phases of matter and what were these? And finally asked properties of each of the three states as discussed in the lesson thereby using her knowledge of conceptual teaching strategies **(CT)** to glue up together from the different bits and pieces which were discussed showing that these are not isolation but work together to form the lesson of the day **Learners' Role:** Class then responded giving teacher the definition of matter, and the three states of matter and also gave teacher the arrangement of particles in liquids and in solids **(LP)** **Teacher Noreen's Role:** The teacher confirmed the student responses. The teacher kept referring back to corresponding representations she had on the blackboard throughout this discussion in her confirmations of her learners' responses **(RP)** In the teaching segment above, four TSPCK components were used and these were LP/CS/CT. The resulting TSPCK Map for the above discussed episode is given as follows: 
11: 20 – 12:26 What else can you say about iSolids, sithetha nge properties of solids zithini ezinye mmmh Sesethu? Student: The particles of solids they do not move but they vibrate Teacher: They do not move they vibrate siyamngqinela Class: Yes Teacher: Ikhona enye into ubuzoyithetha Thando, ziphelile ngoku? Kutheni ungathethi xa zingaphelanga ….mmmmh ithini enye ngubani omnye onento ayikhumbulayo about solids yeyiphi enye into oyikhumbulayo, Yes Sisi Student: The forces of attraction between the particles are strong Teacher: The force of attraction pulls them together to be fixed	**Comment:** In this teaching segment, the focus was on the concept difference in spaces between particles of solids **Teacher Noreen's Role:** The teacher recapped on the concept of particles of solids and asked learners what they could say about properties of solids. In doing so, teacher Noreen is drawing from her knowledge of teaching strategies to assess what learners have learnt and to give them an overall picture of the lesson in case they think the different concepts, which they learnt, were different topics instead of various concepts, which make the topic of particle nature of matter (CT). **Learner's Role:** Learner XF responded that particles of solids do not necessarily move but rather vibrate **(LP)** **Teacher Noreen's Role:** what else did they remember about particles of solids **Learner's Role:** Learner XG that the particles of solids had strong intermolecular forces between their partilces **(LP)** **Teacher Noreen's Role:** The teacher reapeted what student XG said and further explained that bthe forces of attraction between particles were the ones responsible for pulling particles close together causing them to vibrate in fixed positions (CS) In the teaching segment above, three TSPCK components were used and these were LP/CS/CT. The resulting TSPCK Map for the above discussed episode is given as follows

	
12:26 – 15:45 Teacher: What else bayathetha abantu, what else bayathetha abantu ikhona enye into oyilhumbulayo…sithethe nge forces sathetha nge arrangement sathetha nge movement andithi okay masigqithe siye kwi Liquid particles besitheni Nqagi? Student: Liquids are loosely packed in a disorderly manner Teacher: What else? Ngubani omnye okhumbula ntoni? Mmmmm ikhona into onoyithetha nge forces? Khoyithethe Student: Forces of attraction are weak because of kinetic energy Teacher: Sit down sisi, ikhona into ofuna uyithetha Iphendulwe? Student: Xolo Miss they are hard to compress Teacher: iLiquids azicishileleki nhe but besithe kqala iSolids zona are closely packed together andithi and there are small spaces in so much that they cannot move but they vibrate but iliquids zona they are loosely packed together there are spaces between them they are hard to compress andithi? Uyakwazi ucompresa but kancinci if uba ngaba ufake kwesa Syringe ugalele amanzi ungasigcwalisi uvale phaya xa ucompressa uzama ucishilela amanzi ithi nje kancinci awukwazi kucishilela amanzi kude kucasba ucishilele kuaybonakala andithi ivele ime lanto ingahambi iyicishilele uncame	**Comment:** In this teaching segment, the focus was recapping on particles of liquids **Teacher Noreen's Role:** The teacher recapitulated on the concept of particles of liquids and asked learners what they could say about particles of liquids. **Learner's Role:** Learner XH responded that particles of liquids were loosely packed in a disorderly manner, another learner responded when teacher asked them what else they could say about forces and learbner XI responded that forces of attraction were weaker because of kinetic energy and another learner XJ sated that they were not easily compressible **(LP)** The teacher confirmed the learner responses explaining to learners that particles of liquids were loosely packed together and there were spaces between their particles, which were not as small as those of solids **(CS)**. The teacher further reminded learners liquids were hard to compress and refered them to a demonstration **(RP**) which they perfomed in class to emphasise the key concepts. In the teaching segment above, three TSPCK components were used and these were LP/RP/CS. The resulting TSPCK Map for the above discussed episode is given as follows 
15:45 – 19:07 okay eeehhhh igases zona can you compress gases Class: No Teacher: Niyakwazi UCompressa Class: Yes Teacher: kukuthini Class: Kukucinezela Teacher: Okay…masithathe unayo ipicture yesaSyringe unayo ipicture yaso, ugalele amanzi uyivale phaya ukwenzeluba angaphumi upresse kengoku kuyacishileleka? Class: No Teacher: Ayiphushekinhe? Ayiphusheki? Okay…..xa iEmpty uyivale uphinde uyicinezele kwenzekantoni. Class: Mumbles Teacher: Ihamba kancinci? [class: Yes] niyaphosisa Class: Ayi Movi Teacher: Ayi Movie? AyiMovi xa inganamanzi, huh? Ninazo ezazinto ekhaya? Zikhona? Class: Yes and some NO	**Comment:** In this teaching segment, the focus was recapping on compressibility of gases **Teacher Noreen's Role:** The teacher then asked learners if they can compress gases **Learner's Role:** Learners responded with a *'yes'* **(LP)** **Teacher Noreen's Role:** The teacher further reminded learners about the demonstration **(RP**) which they perfomed in class to prompt learner's response on this concept. The teacher asked learners what happens when you close the mouth of a syringe filled with air and push the syringe down. **Learner's Response:** Learners said it would move slowly. **Teacher Noreen's Role:** The teacher confronted the learner misconception by learners as she told them that they were not correct to think when you close the mouth of a syringe filled with air and push the syringe down, it will be difficult to push the syringe and further told learners that its only liquids that are hard to compress but gases were easily compressible **(CS)**

<table>
<tr>
<td>Teacher: Zikhona nhe okay thank you sizozama ukuza nazo siyenze siyibone niyeva at least umoya wona can be compressed kancinci but manzi ona are hard to compress igases zona are easily compressed
Class: Yes and some No
Teacher: Suvuma because ndisitsho because sizoyenza ngomso niyeva, ndizoza nazo
Class: Yes Miss</td>
<td>In the teaching segment above, three TSPCK components were used and these were LP/RP/CS. The resulting TSPCK Map for the above discussed episode is given as follows:

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

APPENDIX 19: Information sheet to teachers

University of Witwatersrand. Education Campus, Science and Technology Division; 27 St Andrew Road; Parktown.

Email: nonkanyiso.vokwana@gmail.com Cell: 0769121200

INFORMATION SHEET TO TEACHERS

Circuit 10

Mqanduli district,

Mthatha

DATE: 10/08/2015

Dear Natural Science Teacher

My name is Nonkanyiso Vokwana. I am a student in the School of Education at the University of the Witwatersrand.

I am doing research on implementation and evaluation of the effectiveness of a Topic Specific Pedagogical Content Knowledge (TSPCK) professional developmental programme for supporting Natural Science teachers in the rural schools of the Eastern Cape Province. These teachers are of interest to the study because they are teaching out of the field of their qualification.

My research involves exploration of the extent of development of the teachers' TSPCK in a specific topic - 'particulate nature of matter' and their content knowledge of the topic as a result of participating in the programme. Thus an intensive intervention programme will be conducted to introduce Natural science teachers to the construct of TSPCK. I will use the following tools to collect data for this study: TSPCK instruments to collect data on science teachers' current understanding of content in this topic and their level of PCK in this topic. An intervention programme will then follow where an observation checklist and an audio video recorder will be used to capture teacher interactions during the intervention. The intervention will take place in the local venue where teachers normally meet for their professional development programmes and I will stick to their normal timetable of these programmes. After the intervention I will join out of field natural science (chemistry) teachers during their normal classroom lessons, the audio-video camera recorder will be focused on the teacher and not the students. Even though the recording will be focusing on teachers alone, I will ask learners' permission to put a video recorder in your classroom which involves your learners to capture teacher interactions with learners during these lessons. I will strictly adhere to the school timetable. After the lesson, I will conduct a brief audio- recorded post lesson interview session with the teacher(s) to reflect on the observed lesson. The study will take place at the end of third term, during school holidays and intervention will take place over Easter holidays.

The reason why I have chosen you to participate in this study is because, you happen to be one of the natural science teachers teaching under such inconveniencing circumstances which involve teaching subject areas which you were never trained to teach. A programme that aims at teaching ways of pedagogically transforming content using the TSPCK framework of five components will be developed.

You are kindly invited to participate in my study as one of the main respondents. Your name and identity will be kept confidential at all times and in all academic writings about the study. Please note that the data gathered might be used for publications and conference presentations as part of my study but individual privacy will be maintained in all published and written data resulting from the study.

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

You will not be advantaged or disadvantaged in any way. Your participation is voluntary, so you can withdraw your permission at any time during this project without any penalty. There are no foreseeable risks in participating in this study and you will not be paid any allowance for this study. However you will be allowed to access the research findings once they are published.

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

Nonkanyiso Vokwana

Email address nonkanyiso.vokwana@wits.ac.za

Tel 0769121200/0117173405

Teacher's Consent Form

Please fill in and return the reply slip below indicating your willingness to be a participant in my voluntary research project called: Investigating the development of Topic Specific Pedagogical Content Knowledge (TSPCK) for Natural Science teachers who are practising out of field in a rural context.

I, ________________________ give my consent for the following:

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

I agree that the following documents; interview guides, classroom checklist and an audio-video camera recorder can be used for this study only. YES/NO

Permission to observe you in class

I agree to be observed in class teaching. YES/NO

Permission to be interviewed

I would like to be interviewed for this study. YES/NO

I know that I can stop the interview at any time and don't have to

answer all the questions asked.

Permission to be audio taped

I agree to be audio recorded for the lessons pertaining to this study only YES/NO

I know that the recorded lessons will be used for this project only YES/NO

Permission to be videotaped

I agree to be videotaped in class. YES/NO

I know that the videotapes will be used for this project only. YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I do not have to answer every question and can withdraw from the study at any time.
- I can ask not to be audio taped and/or videotape
- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date___________________________

APPENDIX 20: Letter to the principal

University of Witwatersrand. Education Campus, Science and Technology Division; 27 St Andrew Road; Parktown.

Email: nonkanyiso.vokwana@gmail.com Cell: 0769121200

LETTER TO THE PRINCIPAL

Circuit 10

Mqanduli district,

Mthatha DATE: 10/08/2015

Dear Sir/Madam,

My name is Nonkanyiso Vokwana. I am a student in the School of Education at the University of the Witwatersrand.

I am carrying out a study that at Marang Centre for Maths and Science Education. My project designs a professional development programme for supporting Natural Science teachers in the Eastern Cape Province who are practising out of field. These teachers are of interest to the study because they are teaching out of the field of their qualification. The study envisages develop both the teachers' content knowledge and knowledge for teaching specific topics in Natural Science by exposing them explicitly to the framework of Topic Specific Pedagogical Content Knowledge. The topic of interest is particle nature of matter which is introduced largely at Grade 8 and forms bases to chemistry understanding, generally. Particle nature of matter therefore is considered as one of the fundamental concepts in chemistry.

The reason why I have chosen your school is because one of the respondents to my study is a member of your schools' teaching staff, from whom I intend to conduct an intervention of TSPCK. A programme that aims at teaching ways of pedagogically transforming content using the TSPCK framework of five components will be developed.

I will use the following tools to collect data for this study: a teacher's pre-lesson interview guide for the out of field natural science teachers, an observation checklist and an audio video recorder to capture teacher interactions during the intervention. After the intervention the audio-video camera recorder will be focused on the teacher and students become involved by default since I will therefore be joining the out of field natural science (chemistry) teachers during their normal classroom lessons. I would like to ask permission from you to conduct these videos during classroom lessons. I will strictly adhere to the school timetable.

After the lesson, I will conduct a brief audio- recorded post lesson interview session with the teacher(s) to reflect on the observed lesson. The study will take place at the end of third term, during school holidays and intervention will take place over Easter holidays.

I kindly request your permission to conduct my research in your school as outlined above. I am aware that learners are involved and have prepared information and consent forms for them and their parents. The research participants will not be advantaged or disadvantaged in any way. They will be re-assured that they can withdraw participation in the research at any time during this project without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid any allowances for this study.

The names of the research participants and identity of the school will be kept confidential at all times and in all academic writings about the study. Please note that the data gathered might be used for publications and conference presentations as part of my study but individual privacy will be maintained in all published and written data resulting from the study.

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

Please let me know if you require any further information. I look forward to your response as soon as is convenient.

Yours sincerely,

Nonkanyiso Vokwana

Email address Nonkanyiso.vokwana@gmail.com

Tel 076 912 1200/011 717 3405

School Principal Consent Form

Please fill in the reply slip below if you agree to participate in my study called: Investigating the development of Topic Specific Pedagogical Content Knowledge (TSPCK) for Natural Science teachers who are practising out of field in a rural context.

My name is: ________________________

Permission to review/collect documents/artifacts	**Circle one**
I agree that my school will participate in this study	YES/NO
Permission to observe you in class	
I agree to observations of lessons in class.	YES/NO

Permission to be audio taped

I agree to the audio recording of the lessons pertaining to this study only YES/NO

I know that the recorded lessons will be used for this project only YES/NO

Permission to be a video taped

I agree to the video recording of the lessons pertaining to this study only YES/NO

I know that the recorded lessons will be used for this project only YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I can ask, and my teacher and learners can ask, for the lessons not to be videotaped.
- The teacher and students will not be compelled to participate but voluntarily agree.
- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date___________________________

APPENDIX 21: Information sheet to learners

University of Witwatersrand. Education Campus, Science and Technology Division; 27 St Andrew Road; Parktown.

Email: nonkanyiso.vokwana@gmail.com Cell: 0769121200

LETTER TO THE LEARNERS

Circuit 10

Mqanduli district,

Mthatha

INFORMATION SHEET LEARNERS

DATE: 10/08/2015

Dear Learner

My name is Nonkanyiso Vokwana. I am a student in the School of Education at the University of the Witwatersrand.

I am doing research on- implementation and evaluation of the effectiveness of a Topic Specific Pedagogical Content Knowledge (TSPCK) professional developmental programme for supporting Natural Science teachers in the rural schools of the Eastern Cape Province. These teachers are of interest to the study because they are teaching out of the field of their qualification.

My study is primarily concerned with the knowledge that enables the teacher to transform the subject matter knowledge into an understanding by students. The study involves how we can improve teaching and learning in our schools for better performance in natural sciences, specifically in chemistry. I am planning to run an intervention programme with Natural Science teachers who are teaching the subject out of their field of expertise. In the intervention programme I will introduce these teachers to TSPCK. I will use the following tools to collect data for this study: TSPCK questionnaires to collect data on science teachers' current understanding of content in this topic and their level of PCK in this topic. An intervention programme will then follow where an observation checklist and an audio video recorder will be used to capture teacher interactions during the intervention. The intervention will take place in the local venue where teachers normally meet for their professional development programmes and will adhere to their normal timetable of these programmes. After the intervention I will join out of field natural science (chemistry) teachers during their normal classroom lessons, the audio-video camera recorder will be focused on the teacher and not the students.

Even though the recording will be focusing on teachers, but because your teacher might be moving around and having small discussions with groups I might need your permission therefore to put a video recorder in your classroom and capture the interactions between you and your teacher. I will strictly adhere to the school timetable. After the lesson, I will conduct a brief audio- recorded post lesson interview session with the teacher(s) to reflect on the observed lesson. The study will take place at the end of third term, during school holidays and intervention will take place over Easter holidays.

I was wondering whether you would mind if I invite you to take part in our study as a participant. I intend to sit in your natural science classroom, during the normal learning sessions and observe how your teacher teaches natural sciences. I will also use video tape recorder to record the lessons. The focus of the audio-video tape recorder will be mainly on your natural science teacher only.

I will not be requiring anything from you other than your permission to video record the lessons you sit in. Remember, this is not a test, it is not for marks and it is voluntary, which means that you don't have agree. Also, if you decide halfway through that you prefer me to stop recording you, this is completely your choice and will not affect you negatively in any way.

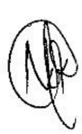
Please note that the data gathered might be used for publications and conference presentations as part of my study but individual privacy will be maintained in all published and written data resulting from the study. Also, all collected information will be stored safely and destroyed between 3-5 years after the completion of this project.

Your parents have also been given an information sheet and consent form, but at the end of the day it is your decision to join us in the study.

I look forward to working with you!

Please feel free to contact me if you have any questions.

Thank you yours sincerely,



Nonkanyiso Vokwana

Email address: nonkanyiso.vokwana@gmail.com

Tel 0769121200/011 717 3405

Learner Consent Form

Please fill in the reply slip below if you agree to participate in my study called: Investigating the development of Topic Specific Pedagogical Content Knowledge (TSPCK) for Natural Science teachers who are practising out of field in a rural context.

My name is: ________________________

Permission to review/collect documents/artifacts	Circle one
I agree that I will participate in this study as a learner in the class	YES/NO
Permission to observe you in class	
I agree to be observed in class.	YES/NO
Permission to be audio taped	
I agree to be video recorded during the observation lesson	YES/NO
I know that the videodiotapes will be used for this project only	YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I can ask not to be video recorded taped.
- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign_____________________________ Date__________________________

APPENDIX 22: Information sheet to parents

University of Witwatersrand. Education Campus, Science and Technology Division; 27 St Andrew Road; Parktown.

Email: nonkanyiso.vokwana@gmail.com Cell: 0769121200

INFORMATION SHEET PARENTS

Circuit 10

Mqanduli district,

Mthatha

DATE: 10/08/2015

Dear Parent

My name is Nonkanyiso Vokwana. I am a student in the School of Education at the University of the Witwatersrand. I am carrying out a study on implementation and evaluation of the effectiveness of a Topic Specific Pedagogical Content Knowledge (TSPCK) professional developmental programme for supporting Natural Science teachers in the rural schools of the Eastern Cape Province. These teachers are of interest to the study because they are teaching out of the field of their qualification.

My study is primarily concerned with the knowledge that enables the teacher to transform the subject matter knowledge into an understanding by students. The study involves how we can improve teaching and learning in our schools for better performance in natural sciences, specifically in chemistry. I am planning to run an intervention programme with Natural Science teachers who are teaching the subject out of their field of expertise. In the intervention programme I will introduce these teachers to TSPCK. I will use the following tools to collect data for this study: TSPCK instruments to collect data on science teachers' current understanding of content in this topic and their level of PCK in this topic. An intervention programme will then follow where an observation checklist and an audio video recorder will be used to capture teacher interactions during the intervention. The intervention will take place in the local venue where teachers normally meet for their professional development programmes. After the intervention I will join out of field natural science (chemistry) teachers during their normal classroom lessons, the audio-video camera recorder will be focused on the teacher and not the students. The recording will be focusing on teachers but since the teachers might be interacting with learners while teaching, I would like to get permission to video tape the teacher and your child. I will strictly adhere to the school timetable. After the lesson, I will conduct a brief audio- recorded post lesson interview session with the teacher(s) to reflect on the observed lesson.

The study will take place at the end of third term, during school holidays and intervention will take place over Easter holidays.

I was wondering whether you would mind if I invite you to participate in our study as the parent of your child, by allowing your child to participate in the study. Your child will not be advantaged or disadvantaged in any way. S/he will be reassured that s/he can withdraw her/his permission at any time during this project without any penalty. There are no foreseeable risks in participating and your child will not be paid for participating in this study.

Your child's name and identity will be kept confidential at all times and in all publications such as journal articles, conference presentations and other academic writing about the study. His/her individual privacy will be maintained in all published and written data resulting from the study.

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

Please let me know if you require any further information.

Thank you very much for your help.

Yours sincerely,

Nonkanyiso Vokwana

Email address Nonkanyiso.vokwana@gmail.com

Tel 0769121200/0117173405

Parent's Consent Form

Please fill in and return the reply slip below indicating your willingness to allow your child to participate in the research project called: Investigating the development of Topic Specific Pedagogical Content Knowledge (TSPCK) for Natural Science teachers who are practising out of field in a rural context.

I, ________________________ the parent of ______________________

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

I agree that my child can participate in this study as a learner. YES/NO

Permission to observe my child in class

I agree that my child may be observed in class. YES/NO

Permission to be videotaped

I agree my child may be videotaped in class. YES/NO

I know that the videotapes will be used for this project only. YES/NO

Informed Consent

I understand that:

- My child's name and information will be kept confidential and safe and that my name and the name of the school will not be revealed.
- My child can ask not to be audio taped, and/or videotape
- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date_______________________

APPENDIX 23: Letter to the Eastern Cape Department of Education

University of Witwatersrand. Education Campus, Science and Technology Division; 27 St Andrew Road; Parktown.

Email: nonkanyiso.vokwana@gmail.com Cell: 0769121200

LETTER TO THE HEAD OF THE DEPARTMENT

Steve Vukile Tswete

Education Complex, Zone 6

Zwelitsha

5608 DATE: 10/08/2015

Dear Sir/Madam,

My name is Nonkanyiso Vokwana. I am a student at Wits School of Education. I was until recently a physical sciences and natural sciences teacher at Axium Education which is non-profit organisation in the rural former Transkei region. My responsibilities included, facilitating science teacher at GET and FET level.

I am currently registered as a Doctoral students and my focus is on focusing on science education. My project designs a professional development programme for supporting Natural Science teachers who are practicing out of field in the Eastern Cape Province in Mqanduli region. These teachers are of interest to the study because they are teaching out of the field of their qualification. The study aims at developing both the teachers' content knowledge and knowledge for teaching specific topics in Natural Science by exposing them explicitly to the framework of Topic Specific Pedagogical Content Knowledge. The topic of interest is particle nature of matter which is introduced largely at Grade 8 and forms bases to chemistry understanding, generally. Particle nature of matter therefore is considered as one of the fundamental concepts in chemistry.

I will run an intervention programme with Natural Science teachers who are teaching the subject out of their field of expertise. In the intervention programme I will introduce these teachers to TSPCK. I will use the following tools to collect data for this study: TSPCK instruments to collect data on science teachers' current understanding of content in this topic and their level of PCK in this topic. An intervention programme will then follow where observation checklist and audio video recorder will be used to capture teacher interactions during the intervention. The intervention will take place in the local venue where teachers normally meet for their professional development programmes. After the intervention I will join out of field natural science (chemistry) teachers during their normal classroom lessons, the audio-video camera recorder will be focused on the teacher and not the students. Even though the recording will be focusing on teachers alone, but because the teacher might be moving around and having small discussions with groups I might need your permission therefore to put a video recorder in their classroom. I will strictly adhere to the school timetable. After the lesson, I will conduct a brief audio- recorded post lesson interview session with the teacher(s) to reflect on the observed lesson. The study will take place at the end of third term, during school holidays and intervention will take place over Easter holidays.

The reason I have chosen your schools or teachers is because one of the respondents to my study is a member of your department, from whom I intend to conduct an intervention of TSPCK.

I kindly request your permission to conduct my research in your schools as outlined above. I am aware that learners are involved and have prepared information and consent forms for them and their parents. The research participants will not be advantaged or disadvantaged in any way. They will be re-assured that they can withdraw participation in the research at any time during this project without any penalty. There are no foreseeable risks in participating in this study. The participants will not be paid any allowances for this study.

The names of the research participants and identity of the schools will be kept confidential at all times and in all academic writings about the study. The individual privacy and that of the schools will be maintained in all publications and conference presentations and all other written data resulting from the study.

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

Should you require any further information, please do not hesitate to contact me. I look forward to your response as soon as is convenient.

Yours sincerely,

Nonkanyiso Vokwana

Email address Nonkanyiso.vokwana@gmail.com

Tel 076 912 1200/011 717 3405

Head of Department Consent Form

Please fill in the reply slip below if you agree to that your teachers should participate in my study called: Investigating the development of Topic Specific Pedagogical Content Knowledge (TSPCK) for Natural Science teachers who are practising out of field in a rural context.

My name is: ________________________

Permission to review/collect documents/artifacts	**Circle one**
I agree that my schools will participate in this study	YES/NO

Permission to observe you in class

I agree to observations of lessons in class. YES/NO

Permission to be audio taped

I agree to the audio recording of the lessons pertaining to this study only YES/NO

I know that the recorded lessons will be used for this project only YES/NO

Permission to be a video taped

I agree to the video recording of the lessons pertaining to this study only YES/NO

I know that the recorded lessons will be used for this project only YES/NO

Informed Consent

I understand that:

- My name and information will be kept confidential and safe and that my name and the name of my school will not be revealed.
- I can ask, and my teacher and learners can ask, for the lessons not to be videotaped.
- The teacher and students will not be compelled to participate but voluntarily agree.
- All the data collected during this study will be destroyed within 3-5 years after completion of my project.

Sign______________________________ Date___________________________