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Investigating the quality of TSPCK in enactment for fourth (4th) year preservice teachers (PSTs) using digital teaching videos in the topic of Chemical Equilibrium.

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WITWATERSRAND,
JOHANNESBURG

Investigating the quality of TSPCK in enactment for fourth (4th) year pre-service teachers (PSTs) using digital teaching videos in the topic of Chemical Equilibrium.

A research project submitted to the Faculty of Humanities, University of the Witwatersrand in partial fulfilment of the requirement for the degree in Master of Education.

By

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ABSTRACT

The purpose of this study was mainly to examine the nature and quality of Topic Specific Pedagogical Content Knowledge (TSPCK), how it behaves or changes when it is observed from self-recorded teaching videos specifically on the topic of Chemical Equilibrium. This study was performed on a group of preservice teachers (PSTs) at Wits school of Education. The collected data involved lesson plans, reflections, and self-recorded teaching videos. This data was subjected to extensive in-depth qualitative analysis, where TSPCK episodes were identified. The Cohens Kappa coefficient was calculated for the validity of the identified TSPCK episodes. This study found that the nature of TSPCK in teacher lesson plans for self-recorded video lessons appears to remain constraint and limited in visibility. This is because teacher tasks seem to offer very few, specifically only single, opportunities for portraying the teachers' TSPCK even when the planning is for digital recording. Furthermore, it was found that the quality of planned TSPCK (plTSPCK) reflected in the planning of teacher self-video recorded lessons appears to directly influence the quality of enacted TSPCK (eTSPCK) manifesting in the enactment teaching of the planning. Furthermore, higher quality plTSPCK seem to facilitate the visible manifestation of the complex structural change in the interactions of the knowledge components of TSPCK. Implications of this study are that there is a need for reconsideration of new theoretical framework within a digital space which were discussed in this study.

Key words: Preservice teachers (PSTs), TSPCK, eTSPCK, plTSPCK, TSPCK episodes Chemical Equilibrium, self-recorded teaching videos

DECLARATION

I Siphelele Gcwensa (1384516) declare that this research study is my own work. It has not been submitted before for any other degree or examination in any other university. All the work taken directly from other works has been cited accordingly and the full list of references has been provided. I fully understand that the University of the Witwatersrand will take disciplinary action against me if evidence suggests that this is not my own unaided work or that I failed to acknowledge the sources of the ideas or words in my writing.



University of the Witwatersrand, July 2022

Protocol number: *2021ECE110M*

The journey of research is painfully beautiful, but fulfilling, I thank the Lord almighty for the experience and the privilege.

To: Mr and Mrs Gcwensa.

Thank you for your support. Your son is doing well.

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ABBREVIATIONS AND ACRONYMS

CM	Consensus Model
cPCK	Collective Pedagogical Content knowledge
CS	Curricular saliency
CTS	Conceptual Teaching Strategies
d-TSPCK	Digital Topic Specific Pedagogical Content knowledge
ePCK	Enacted Pedagogical Content knowledge
eTSPCK	Enacted Topic Specific Pedagogical Content knowledge
LP	Learner Prior Knowledge
PCK	Pedagogical Content knowledge
plTSPCK	Planned Topic Specific Pedagogical Content knowledge
pPCK	Personal Pedagogical Content knowledge
PSTs	Preservice teachers
RCM	Refined Consensus Model
RP	Representations
TSPCK	Topic Specific Pedagogical Content knowledge
WD	What is difficult to teach

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CHAPTER 1: INTRODUCTION OF THE STUDY

Abstract

This chapter seeks to outline a brief overview, the background of this study, the rationale, problem statement and purpose of the study. In doing so, this chapter seeks to set the context of this study within the theoretical framework of Pedagogical Content Knowledge (PCK) Framework visualized in a digital realm.

1.1 Introduction: Understanding PCK history, developments, and teaching videos

Teaching is more than the process of disseminating knowledge, competence, and experience to learners beyond their prior knowledge and general conceptions of the world. Instead teaching provides learners with the cognitive and social skills required to succeed, survive, and contribute to society at large (Powell & Kalina, 2009). However, to equip learners with further knowledge, skills, and experience, teaching has to be facilitated in effective specialized methods and strategies that allow for the transformation of content knowledge. It is for this reason that Shulman (1987) argued that, in order to effectively teach, teachers require more than merely knowing and comprehending content knowledge for themselves. They need to teach content knowledge in meaningful ways that will enhance learner understanding. To achieve this, teachers must go beyond knowing content knowledge for themselves and enter the realm of how to transform knowledge for the benefit of their learners.

As a result, Shulman (1986) introduced an effective teaching construct describing tacit teacher professional knowledge for teaching and learning, which he called Pedagogical Content Knowledge (PCK). According to de Sá Ibraim and Justi (2021), PCK describes a teacher's specific knowledge that guides the teaching and learning profession in terms of how to transform content knowledge in ways that will make it easily accessible to the learners.

Building from the existing PCK constructs, Mavhunga and Rollnick (2013) introduced the concept of Topic Specific Pedagogical Content Knowledge (TSPCK), which looks at the transformation of content knowledge at a topic specific level. According to de Sá Ibraim and Justi (2021), the TSPCK concept introduced the practicality of PCK within a classroom setting because the emphasis is on transforming specific topics, as a teacher does in a classroom per lesson. As a result, this study focuses on exploring TSPCK on the topic of Chemical

Equilibrium within the realm of enactment but in the form of a recorded teaching video that could be digitally accessed by learners as a lesson.

1.2 The background of the study

This study takes its prominence from years of successful research in TSPCK construct and the new need to move from traditional teaching settings into digital teaching settings as demanded by changing global trends, e.g., COVID -19 (Mavhunga et al., 2022). de Sá Ibraim and Justi (2021) described TSPCK as an effective and successful construct for both pre-service and experienced teachers in different countries. Nonetheless, it is important to note that throughout these studies, TSPCK is observed from planning and enacted perspectives in a traditional classroom environment. This means the notion of enacting planned TSPCK (plTSPCK) in a digital teaching dimension is yet to be explored. Hence, little is known about the enactment of TSPCK in the digital realm. As a result, this study begins the exploration of PCK in a transition mode from a traditional classroom into a digital classroom realm.

At this beginning stage, this specific study simply explores the changes, if any, of TSPCK when a self-video recorded lesson is designed and recorded digitally. It is important to note that this study continues to employ the TSPCK construct as it is traditionally defined in previous studies (Malcolm & Ndlovu, 2022; Mavhunga & Rollnick, 2013). It is believed that the findings from this study, will inform the next set of research studies exploring TSPCK in a digital realm in order to develop a full picture as it has been done with the traditional TSPCK construct. Furthermore, this study will contribute towards closing the paucity of studies exploring TSPCK in a digital realm given that the digital realm has not been defined even in the current PCK new Refined Consensus Model (RCM) (Carlson & Daehler, 2019).

Harrison (2020) articulated that educational videos created by teachers to meet learners' learning specific needs are an emerging revolution that is slowly being introduced to the education field. Henceforth, Bozkurt and Sharma (2020) state that when COVID-19 began in 2019, it resulted in several countries across the globe applying national shutdowns such as lockdowns of basic and higher institutions of learning. According to numerous studies, the global pandemic posed a challenge to the global education system, forcing the development of innovative ways to conduct learning in an online digital learning environment(Al Lily et al., 2020; Bozkurt & Sharma, 2020).

Consequently, digital videos were one of the digital medium that were employed widely as a solution for online, remote learning as necessitated by the COVID-19 pandemic (Peimani & Kamalipour, 2021). This is due to the fact that videos offer a more affordable technology as compared to other advanced technologies such as live online classes (Onyema et al., 2020). In the quest for accessible and affordable methods to digitalisation of TSPCK, this study explores the visible TSPCK in self-recorded teaching videos on Chemical Equilibrium in the context of initial teacher development in South Africa.

1.3 Rationale of the study

Science, Technology, Engineering and Mathematics (STEM) subjects are significant subjects in developing countries like South Africa as they help to equip the country with necessary skills of advancing its developments (Onyema et al., 2020; Young & Muller, 2013). As a result, maintaining effective teaching and learning that promotes access to content understanding of these disciplines is critical for the country's' youth to pursue STEM career fields and contribute to the country's successful globalization. Hence, this study looked at ways for developing science learning in a digital realm for the promise it offers for portability and multiple accessibility. In doing so this study looked at how TSPCK can be visualised on preservice teachers (PSTs) self-recorded teaching videos in the topic of Chemical Equilibrium.

1.3.1 Why videos?

South Africa is one of the developing countries that have been left behind in the digital transition state in line with global changes. There are significant differences between rural and urban areas in terms of technological development (Olaniran & Maphalala, 2020). This signifies a need to implement affordable and user-friendly technologies like videos to be taken advantage of in preparing South African teachers to be able to teach within digital spaces. Onyema et al. (2020) noted teachers' incompetence in engaging with technologically platforms during online learning conscripted by COVID-19 indicating a need for teacher professional development in this field.

This requires teacher technological pedagogical transformation to export what they know from a traditional space into a digital space. However, as much as technological skills are a challenge, there is also a lack of theoretical frameworks to transform content knowledge within a digital realm. Likewise, TSPCK/PCK frameworks have been serving teacher science

education in traditional classroom space (de Sá Ibraim & Justi, 2021). However, they are beginning to show visible weaknesses in manifesting in the digital realm, necessitating the understanding of how TSPCK can be visualized within the digital realm, which this study aimed to achieve. Thus, this study in addition to informing the next generation of research studies, it aims at contributing towards the potential development of new conceptual frameworks for TSPCK in the digital realm.

While teaching videos offer accessible and cost effective technology, researchers warn about their proliferation and simple copy and paste use (Bozkurt & Sharma, 2020; Onyema et al., 2020). The authors state that the advancement of technology has caused educational videos to be readily available on the internet. This raises concern about the accuracy of content knowledge found in random educational teaching videos on the internet since the content and analogies or simulations used can be misleading (Rajadell & Garriga-Garzón, 2017). In view of this observation, Harrison (2020) states that there is a need for research in the pedagogy of educational videos focusing both on the perception of students who watch them as well as the teachers who create the videos. Bozkurt and Sharma (2020) add that teaching, even in a digital format, is a complex process that has to be carefully planned, designed, and have clear aims to be achieved for effective learning. Hence, it important that science educators begin to understand how the TSPCK construct manifest in teaching videos.

1.3.1. Why the topic of Chemical Equilibrium?

The topic of Chemical Equilibrium has been studied using TSPCK construct in several studies in a traditional classroom setting and they have had success in developing TSPCK of PSTs in this topic (Makhechane & Mavhunga, 2021; Rollnick & Mavhunga, 2014). Furthermore, Mavhunga and Rollnick (2011) established a validated tool for measuring TSPCK in the topic of Chemical Equilibrium. On another perspective, Mensah and Morabe (2018) articulated that previous studies have shown that students find the learning of the topic of Chemical Equilibrium to be one of the challenging topics. Hence, South African learners develop numerous misconceptions and struggle to conceptually reason in this topic especially learners from lower performing schools (Mensah & Morabe, 2018). Thus, Chemical Equilibrium is one of the difficult and abstract topics that learners find challenging to understand (Jusniar et al., 2020). Therefore, a need emerges to develop PSTs' TSPCK in the topic of Chemical Equilibrium in order to teach it in a digital realm.

1.4 Problem statement

There is a shift caused by current demands to have alternative ways of how effective teaching can be conducted within a digital space, resulting from the COVID-19 push and the globalization of the world associated with technological advancement and adaptability in educational spaces (Bozkurt & Sharma, 2020; Chen et al., 2022). In line with global changes like the pandemic, there is also a need for educators to improve digital skills and for learners to be adaptive to technological advancement (Onyema et al., 2020). As part of the Fourth Industrial Revolution (4^{th} IR), which is a convergence of technologies that blurs the physical, digital, and biological realms in teaching and learning approaches, technological skills are of paramount importance (Ocholla & Ocholla, 2020). This calls for teachers to adapt to educational changes as there is a need for teachers to be able to teach at a distance and be competent in the 4^{th} IR, especially the PSTs. This is because we need to ensure that they are fully equipped to deal with technology before they begin teaching.

Rajadell and Garriga-Garzón (2017) indicated concern about educational videos being readily available online and the ability for them to be created by anyone, even people who are not educators or educational practitioners. This results in possible misinformation and inaccurate knowledge representation that can lead to students' misconceptions. Thus, this study focused on TSPCK as one of the matured research theoretical frameworks to improve how educational videos can be constructed in ways that speak to accurate teaching practices.

1.5 Aims and Objectives

Teaching in educational videos involves two main aspects, the teacher and the learner aspect (Harrison, 2020). The teacher aspect focuses on how the teacher plans and designs a lesson suitable for the diversity and context of the targeted learners. The learner aspect is on the receiving end, in terms of how the learner receives and interacts with the given digital lesson (Harrison, 2020). In this study, the focus was on the teacher aspect, particularly teacher education within the School of Education at the University of the Witwatersrand. The main purpose and aim of the study were therefore to examine the nature and quality of TSPCK, how it behaves or changes when it is observed from self-recorded teaching videos specifically on the topic of Chemical Equilibrium. Following below are the research main and sub-questions emerging from the purpose of this study.

1.6 Research main question

What is the nature and quality of PSTs' TSPCK displayed in teacher, self-recorded teaching videos on the topic of Chemical Equilibrium?

1.6.1 Research sub-questions

1. What is the nature and quality of PSTs' TSPCK in the planning for teaching Chemical Equilibrium through a teacher self-recorded teaching video?
2. What is the nature and quality of PSTs' enacted TSPCK (eTSPCK) in self-recorded teaching videos on Chemical Equilibrium?
3. What is the relationship between the nature and quality of planned TSPCK (plTSPCK) and enacted TSPCK (eTSPCK) in teacher self-recorded teaching videos on Chemical Equilibrium?

1.7 The significance of the study

The potential impact of this research study is for science teachers to embrace the introduction of technological advancements such as the 4^{th} IR. Furthermore, this study employs enactment of traditional TSPCK in a video format as a way of improving the quality of presented knowledge in teaching videos. This study potentially prepares PSTs for future uncertainties and equips them with necessary pedagogical and digital skills that will not only be required during times of pandemics like COVID-19, but that will also be effective even in the post COVID-19 era.

The significance of this study in the field of science education lies in expectations that its findings would inform teacher education programs aimed at fostering the development of PSTs' TSPCK in the digital realm. In addition, this study envisage contribution to PCK literature regarding the nature and manifestations of eTSPCK in the digital realm, as it demonstrates awareness of how teacher digital competence facilitates or impedes the realisation of eTSPCK within digital space. This could potentially prepare PSTs training programs to welcome technological advancements by providing accurate lessons within a video digital platform guided by TSPCK construct.

1.8 Potential new knowledge from this study

The first piece of potential new knowledge that can emerge from this study is the digital version of eTSPCK. This covers potential constraints and barriers to the implementation of TSPCK in the digital realm that should be considered when creating teaching videos. This study may pave the way for new prospective frameworks regarding TSPCK in the digital realm which can guide effective manifestation of TSPCK in a digital space. Furthermore, this study provides a prospective overview of PSTs' ability to create self-recorded digital videos in a South African setting, in response to global change demands.

1.9 Outline of chapters

This research study is divided into five chapters: Chapter 1 introduces the study and outlines its purpose, Chapter 2 contains the literature review and theoretical framework of the study, Chapter 3 describes the methodology, Chapter 4 provides the data, subsequent analyses, and findings. The last Chapter 5 concludes with the findings of the study.

CHAPTER 2: LITERATURE REVIEW

Abstract

This chapter briefly unpacked the gains in the success of traditional PCK by firstly highlighting the move of PCK to TSPCK. This chapter further described current developments in the community of TSPCK/PCK and explored the movement to digital education with the use of teaching videos. In addition, this chapter justified why this study believes that videos can be an advantageous mode of teaching during and post COVID-19 era. Hence, the need of research in digital pedagogies for creation of videos conducive for teaching and learning.

2 Recent Literature Review

2.1 A move from PCK to TSPCK

The PCK construct was first introduced by Shulman (1986) which he defined as, "the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that makes it comprehensible for others" (Shulman, 1986, p. 9). Hence, PCK is commonly viewed as specialized knowledge that a teacher develops with time and through experience, which allows the teacher to transform a particular content knowledge and make it easily accessible to others (de Sá Ibraim & Justi, 2021). Furthermore, PCK is broad and normally positioned at discipline level, and consists of multiple taxonomies that will later be discussed in this chapter when unpacking the new Refined Consensus Model (RCM) of PCK (Carlson & Daehler, 2019).

2.2 How is TSPCK distinguished from PCK?

TSPCK is different from PCK in a sense that it focuses on strategies to transform a specific topic within science curriculum (de Sá Ibraim & Justi, 2021). In contrast, PCK is similar to TSPCK in a manner that these two teaching constructs are both tacit teacher's professional knowledge for transforming subject matter knowledge (de Sá Ibraim & Justi, 2021). Hence, PCK as a construct is an umbrella of different realms or taxonomies that work together towards the achievement of successful learning and teaching of a certain subject matter as defined in the new RCM of PCK (Carlson & Daehler, 2019).

The construct of TSPCK by Mavhunga and Rollnick (2013) is described as one of grain size PCK in the new RCM as it is acknowledged and valued in the PCK community (Carlson &

Daehler, 2019). The contribution of TSPCK has been acknowledged and recognized by the PCK community as one of effective models for transforming content knowledge in a specific topic to make it easily accessible for the learners (de Sá Ibraim & Justi, 2021).

2.3 TSPCK practical implications

Furthermore, Mavhunga and Rollnick (2013) proposed practical ways in which TSPCK can be taught to PSTs and in-service teachers using intervention programs. Hence, there have been several intervention studies of pre-service and in-service teachers that have been conducted in different countries to improve or develop TSPCK of both pre-service and in-service teachers (Makhechane & Mavhunga; Shinana et al., 2021; Vollebregt, 2020). Moreover, TSPCK has been studied in terms of its nature, ranging from the nature of plTSPCK to the nature of eTSPCK in physical contact classrooms (Carlson & Daehler, 2019). In understanding the nature of TSPCK recent studies such Mavhunga and van der Merwe (2020) discovered that TSPCK undergo structural change from plTSPCK to eTSPCK while the intentions of the lessons remain unchanged. Such findings were explored in this study whether they are exclusive to TSPCK enactment in a traditional classroom or whether they could be observed similarly in a digital realm.

On another hand, there have been scholars studying methods or strategies of measuring the construct of TSPCK, which also developed tools for measuring TSPCK in different topics (Malcolm et al., 2019). The construct has also been investigated or studied in terms of TSPCK and learner achievement, which discovered that learners improved their performance when the teachers were engaged with TSPCK intervention programs (Akinyemi & Mavhunga, 2021). The success of these studies indicates a need to move into researching these working pedagogies within a digital realm. Hence, this study focused on examining the nature and quality of TSPCK, how it behaves or changes when it is observed from self-recorded teaching videos specifically on the topic of Chemical Equilibrium.

2.4 Capturing and measuring the quality of TSPCK

For one to be in possession of excellent or quality TSPCK it is significant to comprehend all five (5) TSPCK components namely, Learner Prior knowledge (LP), Curricular saliency (CS), Representations (RP), what's difficult to teach (WD), and Conceptual Teaching Strategies (CTS). Furthermore, not only understand the TSPCK components, but also be able to demonstrate the understanding of the components in practice. Henceforth, TSPCK quality is

measured based on how teacher's show understanding of TSPCK components in practice through continuous use of the components in a complementary interactive manner throughout the lesson (Mavhunga, 2016). As a result, TSPCK is best visible in episodes which are segments or moments in the lesson when there is two or more TSPCK components interacting together in a complimentary manner.

These episodes in which the teacher uses the most of TSPCK components in a complementary manner to transform complex scientific knowledge result in that scientific knowledge being easily understandable to the targeted learners (Akinyemi & Mavhunga, 2021). This is so because, Akinyemi and Mavhunga (2021) linked the quality of eTSPCK in terms of components interaction with the learner outcome. Their findings proved that transforming a specific topic using high quality TSPCK evidenced through TSPCK components interaction, allows learners' to significantly gain epistemological access in that specific topic (Akinyemi & Mavhunga, 2021). The evidence of this was through improved learner topic outcome or performance post the intervention program that improved the quality of PSTs quality of eTSPCK (Akinyemi & Mavhunga, 2021). Likewise, complimentary TSPCK component interaction is the major unit of analysis in the measure of the quality of plTSPCK and eTSPCK.

2.5 The measuring of TSPCK

The complimentary interaction of TSPCK components is one of the validated methods to measure TSPCK quality. Park and Chen (2012) were the first to introduce the method of PCK component interactions called PCK maps. According to Park and Chen (2012), PCK maps represents integrated TSPCK/PCK components interactions using circles representing the components. The linear kinds of TSPCK components interaction are represented with circles set in a linear series with an arrow in between pointing to the following component, while other forms of interaction are shown with the circles with PCK/TSPCK components interacting together in a clustering manner (Mavhunga & van der Merwe, 2020). Different studies have adopted this TSPCK/PCK maps method in analysing the quality of plTSPCK and eTSPCK in different episodes (Akinyemi & Mavhunga, 2021; Mavhunga & van der Merwe, 2020).

The TSPCK maps have been used simultaneously with TSPCK rubrics. For example, Mavhunga and Rollnick (2013) developed a rubric used to measure the quality of plTSPCK. The developed rubric has five TSPCK components, each TSPCK component has a four-point scale rating from (1) one as *limited* up to four (4) as *exemplary*. The major significance in the

rubric is the interaction of TSPCK components in a complimentary manner. Thus, this study used TSPCK maps and rubrics to measure the quality of plTSPCK and eTSPCK of PSTs in lesson plans and self-recorded teaching videos. A detailed description of TSPCK maps and the rubrics will be discussed in greater details on the methodology chapter of this study.

2.6 Significance of equipping pre-service teachers with PCK/TSPCK

The importance of equipping PSTs with TSPCK/PCK rests in the fact that when most PSTs begin their education courses, they are unaware of teacher cognitive demands that affect the teaching profession (Nilsson & Loughran, 2012). PSTs enrol in education undergraduate degrees without deep conceptual reasoning and expert knowledge required to teach different topics. Due to insufficient teaching expertise and topic exposure, enrolled PSTs lack conceptual reasoning and knowledge in various topics (Coetzee, 2018). Hence, PSTs have knowledge gaps, scientific inconsistencies, and a lack of logical coherence, resulting in educator errors in their teacher instructional practices.

PSTs' knowledge gaps and misconceptions hinder their ability to construct complex, challenging, and demanding learning environments for PCK development. Tondeur et al. (2020) articulated that to be effective in establishing classrooms where subject matter and pedagogy are mixed to enhance learning, PSTs must first be exposed to such environments (Loughran, 2012). As global trends demand technology fluency, PSTs must be exposed to learning environments that integrate subject matter and pedagogy in a digital realm to prepare them for future occupations and global shifts of technological advancement.

TSPCK/PCK is a useful construct for understanding educators' knowledge, making it useful in teacher education programs (de Sá Ibraim & Justi, 2021). According to Mavhunga and Rollnick (2013) the implications for teacher preparation programs include PSTs learning not only how to teach but also how to teach specific topics. Albareda-Tiana et al. (2018) articulated that teacher education programs could be considered as a primary target for educational improvement within a country as they are the producers of future teachers. Consequently, it is crucial for these institutions to be competent in developing teacher knowledge that will produce effective teachers capable of adequately transmitting content knowledge to their students, regardless of the medium used to mediate content knowledge.

Novice teachers have a limited understanding of the subject they teach. Consequently, their teaching is generally focused on the teacher imparting information or knowledge to learners,

which is ineffective in helping the learners to better understand content knowledge. Thus, PSTs struggle to help learners understand science in a classroom context (Coetzee, 2018). This PST challenge mainly emerge from the result of the divide between theory and practices gap. This stems from understanding teaching theories like PCK taught in teacher preparation programs in relation to practicing them in an actual teaching classroom which requires further practice and experience. However, digital videos provide a potential way to further bridge this theory-practice gap, which will be unpacked in the following topic in this chapter.

2.7 Significance of equipping pre-service teachers with PCK/TSPCK.

In further elaboration, Hume and Berry (2011) articulated that when PSTs enrol for teaching programs they are equipped with different theories, principles and values that guide the practices of their teaching. However, the practical applications of how learnt knowledge links with actual classroom context is left for PSTs to figure out how to apply it, when they complete their studies. Hence, Mavhunga and van der Merwe (2020) indicated that the enduring disconnection gap between theory and practice is because of teachers' knowledge in knowing what to do from the planning stage and enacting what you know in the classroom. Hence, PSTs are left to try to implement the theory in practice, which results in gaps in terms of effectiveness of applying theory into practice, due to factors such as lack of classroom practice experience.

However, PCK is one framework that has been active in bridging the gap between theory and practice. Several studies have indicated videos as good tools for reflection and developing teaching practice (Bruce & Chiu, 2015; Suh et al., 2021; Zhang et al., 2017). Mavhunga and van der Merwe (2020) stated that reflection for action is significant in translating plTSPCK into eTSPCK, while indicating the need and the importance of teacher reflection in action and teacher reflection on action. Where reflection in action is when the teacher is reflecting on the incident while it can still benefit the current situation (Nilsson & Karlsson, 2019). On the other hand, reflection for action is the teachers' reflection before engaging in the event of teaching and learning. Lastly, reflection on action is when a teacher reflect after the event has occurred for the purpose of improving in the future (Nilsson & Karlsson, 2019).

Suh et al. (2021) state that "Video is a powerful tool for inquiry-based professional learning in practice-based settings (Masimbe, 2019) because it gives teachers the unique opportunity to view their own classroom practice, reflect on what they see, and engage in evidence-based discussions that can lead to changes and improvements in their practice" (p. 153). Thus,

teachers can, effectively plan digital teaching videos. Subsequently, transforming content knowledge through TSPCK in the video gives the teacher flexibility to reflecting on action and be able to adapt the teaching to demonstrate a desired level of TSPCK. This is so because pre-recorded digital videos in the preparation stage can be manipulated according to the teacher's desired outcomes using video editing software.

This means the teachers will have the advantage to improve their lesson before it even gets to the learners and the ability to correct any potential mistakes made during the recording of the lesson, can easily be amended with video editing software such as openshot. This gives teachers the freedom to adapt lessons in a way that they will want them to manifest to their learners. Furthermore, it gives teachers an opportunity to revise theories guiding their actual practices in videos and possible recognition of content inaccuracy when reflecting on the video that they have designed for their learners. Hence, videos have a great potential of improving teaching quality and offer excellent learning opportunities for the teacher themselves to improve their teaching and learn from themselves on the spot as articulated by Suh et al. (2021). Thus, content knowledge transformation through TSPCK in digital video can increase the bridging of theory-practice gap.

2.8 Moving TSPCK into a digital realm

The idea of moving TSPCK into a digital realm is not a concept wholly originating from this study, it is however still an emerging new theoretical framework that is not yet fully developed. Hence, this research study aimed at potentially contributing to the emerging theoretical framework of d-TSPCK concerning the visualisation of TSPCK in a digital realm of a video format. This is due to a pressing need to move TSPCK into a digital realm. Hence, Mavhunga, Rollnick and Van der Merwe (in press) introduced a new conceptual framework termed digital-TSPCK (d-TSPCK).

D-TSPCK is an emerging conceptual framework for exploring the transportation of TSPCK into a digital space. It is defined as teacher professional knowledge for digitally transforming science topics, through digital means (Mavhunga et al., in press). Hence, it is termed d-TSPCK, because it is TSPCK reasoned and planned for the purpose of being enacted in a digital platform. The major focus of this conceptual framework still lies in the transformation of content knowledge, however with a new digital outlook. On the other hand, the construct of d-TSPCK is still a newly proposed conceptual framework that draws closely from the traditional

TSPCK, teacher digital competences (UNESCO, 2011) theoretical frameworks and cognitive load theory (DBE, 2022).

It is, however, crucial to note that while I am exploring TSPCK in pre-recorded digital videos, this study is not necessarily a d-TSPCK study. This is so because consensus meaning, practical implications and measuring tools of d-TSPCK are still being developed (DBE, 2022). Hence, the major focus of this study was on the transitioning mode of TSPCK and looking at how traditional TSPCK manifests in practice when the act of teaching practice is captured as a self-recorded lesson. Understanding the way, the TSPCK constructs manifest in traditional classrooms as well as in the intermediate digital form, where the lesson that would have been delivered in a traditional classroom is digitally self-recorded, is important in establishing whether there are fundamental changes in the structure of the construct.

This understanding would be very useful to compare and determine how the structure of digital TSPCK as the construct under construction is similar or different when the lesson if fully immersed in digital teaching platforms as a default means of teaching. Thus, this study is an exploratory study in applying traditional TSPCK into a video format for the purpose of evaluating the affordance of contributing to the current developments of transitioning TSPCK into d-TSPCK.

2.9 The use of teaching videos as a digital platform to create TSPCK guided digital lessons

The pandemic changed traditional teaching and learning methods in many countries across the world (Jones & Sharma, 2020; Masimbe, 2019). This unprecedented shift affected basic and higher institutions of education where teachers were forced to embark on experimental online teaching and learning (Jones & Sharma, 2020). The experimental online learning exposed teacher's, technological incompetence's for teaching in an online environment (Jones & Sharma, 2020; Onyema et al., 2020). This is because the pandemic did not give teachers and learners time to prepare for virtual learning. Power outages, access to technology, internet data, poor network connections, teacher technological incompetence, and home disruption made online learning to be a difficult learning experience especially to people residing within rural areas of developing countries like South Africa (Onyema et al., 2020). This required exploring technologies that can limit these challenges associated with online learning.

Thus, pre-recorded teaching digital videos seem to offer a way out of these challenges. This is so because firstly pre-recorded teaching videos have no live time constraints, which means learners can watch them at any convenient time, hence avoiding issues such as loadshedding. Poor network coverage in South Africa's rural and township areas is a major challenge that hindered online learning during COVID-19 as it demands a stable internet connection (Masimbe, 2019). With pre-recorded digital videos, learners can find a place with better network coverage to download the video and later watch it in a comfortable learning space.
Most South African households cannot afford internet data bundles, due to their high cost (Masimbe, 2019).

This high cost of South African data internet bundles creates social segregation and unequal internet access, where learners from upper-class can afford unlimited internet access and learners from, impoverished communities have limited internet access (Dube, 2020). Hence, not every learner is able to afford synchronous online learning. Hence, videos are more affordable and can reduce the problems caused by expensive data bundles. Masiu and Chukwuere (2018) found that South African learners use smartphones for educational purposes. Hence, digital pre-recorded videos can be compatible with any smart phone provided they are of reasonable size. This means videos can increase educational access, as most people own a smartphone rather than a computer device which is a more expensive option and a demand for online learning (Dube, 2020).

Thus, it is important to explore pedagogies that can transform content knowledge into technologies like videos, which offer easy access and affordability (Lowenthal et al., 2020). Creating videos (video editing) is a skill that is easy to learn, as several studies have shown success in training teachers to design digital teaching videos (Almutairi et al., 2020; Cai, 2022; Zhang et al., 2017). However, this study was different from the above-mentioned studies, in a sense that it focused on visualizing PSTs eTSPCK in self-recorded teaching videos in the topic of Chemical Equilibrium.

2.10 Content knowledge taught through digital videos vs. in physical classroom

Cognitive skills, numeracy skills, and academic knowledge are not the only educational benefits gained in physical schools (Garibaldi & Josias, 2015). Schools also teach social skills,

communication, leadership, teamwork, culture, values, norms, morals, and emotional intelligence through human physical interactions (Du Preez & Roux, 2010; Garibaldi & Josias, 2015). These are skills served by a schooling environment, which are required for competency and living a life of contribution within broader structures of the society (Jones & Sharma, 2020).

To elaborate further, different schools teach their learners different values and cultures. For example, schools teach their learners to respect their teachers in several ways. This is done from simple acts such as standing up and greeting the teacher when they walk into the classroom, depending on a specific school context. Following that, the learners will be expected to be quiet and wait on the teacher's instruction before sitting down or engaging in any other activity. Such cultures assist in the preparation of learners to be functional in hierarchical organisation structures in their future work environments (Du Preez & Roux, 2010). This includes knowing how to respect their employers and fellow colleagues in the workspace. Thus, learning through recorded digital educational videos watched at the learner's convenience in a private space, robs learners of such significant learning opportunities that can only be experienced through human physical interactions.

2.11 Limitations of digital teaching videos

The use of videos for teaching and learning has challenges, such as the lack of visible social clues, when compared to a physical teaching environment. This is so because a teacher can be aware of possible confusion on a learner's face as they are speaking of a certain concept in an actual classroom and address that confusion at the instant, they suspect it. Furthermore, learners can simply ignore the video and not watch it, which can deprive them of the learning opportunity. Hence, the importance of video design that considers important digital media theories like cognitive load theory, which increase learner engagement and promotes active learning within digital platforms (Brame, 2015).

Moreover, there is often a misconception that a digital video on a particular concept can be one-size fits all, meaning one video can be used by different groups of learners from different contexts. According to Zhang et al. (2017) good digital videos are created to suit a specific context of specific learners. Likewise, a teacher with strong PCK knowledge does not use the

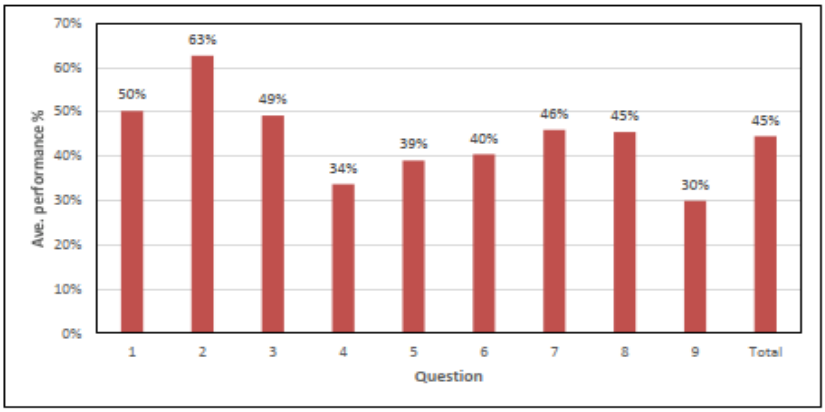
same methods and strategies to teach learners from different contexts but instead adapts pedagogical strategies and skills appropriate for specific groups of learners. Similarly, videos need to be created in a way that suits the needs and context of learners of specific context, in order for the practice of digital videos to be effective (Zhang et al., 2017).

2.12 Exploring Chemical Equilibrium topic

The topic of Chemical Equilibrium is one of the fundamental topics that acts as building blocks for most Chemistry topics (Jusniar et al., 2020). Chemical equilibrium is applicable to most industrial places, which makes it one of fundamentally significant topics for most Chemistry related careers. However, the topic of Chemical Equilibrium is considered as one of the abstract that learners find difficult to understand (Makhechane & Mavhunga, 2021). In support of this, according to South Africa Chemistry diagnostic report chemical equilibrium is amongst one of the topics that learners poorly perform in their annual exams.

As shown in the below **Figure 1** from DBE (2021).

Graph 11.6.1 Average performance per question in Paper 2



Q	Topic	Q	Topic
1	Multiple-choice Questions	6	Chemical Equilibrium
2	Organic Nomenclature and Structures	7	Acids and Bases
3	Physical Properties of Organic Molecules	8	Galvanic Cells
4	Organic Reactions	9	Electrolytic Cells
5	Rates of Reaction		

Figure 1: South African annual diagnostic report in Chemistry topic (DBE, 2021, p. 223)

With reference to above **Figure 1** the average performance of learners in Chemical Equilibrium assessments is 40% which is a poor performance percentage. This indicates that more research has to be conducted in the topic of Chemical Equilibrium to find ways of increasing South African learner performance in this topic. One of the factors that contribute towards poor

performance in the topic of Chemical Equilibrium is various misconceptions that the learners have in this topic (Jusniar et al., 2020; Makhechane & Mavhunga, 2021). Thus, this raises concern towards effective teaching pedagogies in this topic. Hence, in response to this concerning challenges in Chemical Equilibrium, TSPCK studies have been conducted in an attempt to improve learning and teaching of this topic, using intervention programs in PSTs and in-service teachers. These studies have indicated the improvement of the topic within the teaching and learning of Chemical Equilibrium in a traditional classroom environment (Makhechane & Mavhunga, 2021).

In contrast, this topic has not been investigated when taught from a digital point of view. Thus, there is a need for this topic to be investigated in terms of it, manifesting according to TSPCK in a digital realm. This is because Chorianopoulos (2018) indicated that what works in a physical classroom space does not automatically imply it will produce the same results within a video digital platform. Hence, this research was interested in investigating the topic of Chemical Equilibrium within a digital realm as one of the most significant Chemistry topics.

2.13 Theoretical framework

This study is situated in the traditional PCK theoretical framework. The emphasis, however, is on the TSPCK construct, which is identified as one of the grain sizes PCK in the new RCM. As a result, the current PCK model will be unpacked in this section.

2.13.1 The first PCK consensus model

PCK began as a vague and unclear construct, hence different scholars described PCK in different ways. This led to a summit in Colorado Springs on October 12, 2012, by a group of international researchers to come to a consensus understanding and definition of PCK (Gess-Newsome, 2015). This group of researchers worked towards developing the attributes of PCK, the tools for measuring and analysing PCK (Gess-Newsome, 2015). Furthermore, a model of PCK was developed and a shared understanding for viewing the complex nature of PCK was concluded. The developed model was called the first Consensus Model (CM) of PCK (Gess-Newsome, 2015).

However, by 2016 some of the same researchers who attended the first PCK summit and other researchers began to have distinct interpretations and operationalization of PCK. This was due to the affordance and limitations that were later identified in the first PCK consensus model as research and discussions in PCK proceeded (Carlson & Daehler, 2019). Thus, it was noted that

the first PCK model was not detailed enough to properly unpack PCK complexities and layers (Carlson & Daehler, 2019). Therefore, the first PCK consensus model was not able to speak to the multidimensional nature and taxonomies of PCK. Subsequently, as different scholars evaluated the first PCK consensus model, they began to understand what worked and what did not work, which resulted in the revision of PCK research and the first CM of PCK.

2.13.2 The Refined Consensus PCK Model (RCM)

Subsequently, there was a need for a second summit to address the differences in implicit interpretations, and operationalization of PCK. Hence, a second (2nd) PCK summit was held which shifted the focus of the summit from focusing on consensus definitions of PCK, to focusing on analysing research data, approaches, and techniques for capturing and portraying PCK (Carlson & Daehler, 2019). Thus, a new Refined Consensus Model (RCM) of PCK was reborn which clearly articulated different types of PCK's, and how they interact together both in practice and research. This assisted towards a common understanding and a bigger picture for common purpose and focus in PCK (Carlson & Daehler, 2019).

Consequently, the newly introduced RCM of PCK is characterized by three different realms, which are collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK) (Carlson & Daehler, 2019). These realms of complex knowledge develop with individual experience. Furthermore, they shape and inform teacher's classroom practices (Carlson & Daehler, 2019).

The following **Figure 2** shows the current new RCM of PCK together with the realms of PCK as one of the identifying features of this model.

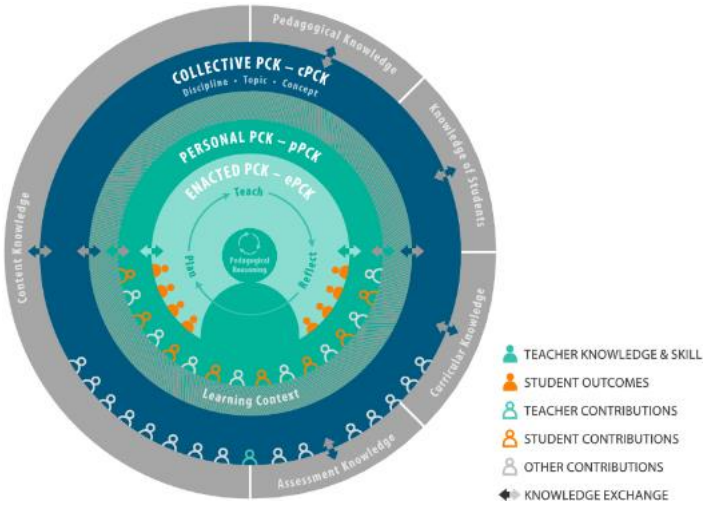


Figure 2: The Refined Consensus Model (RCM) of PCK (Carlson et al., 2019, p. 83)

Collective PCK (cPCK)

This is the first realm of PCK, which is collective professional knowledge formed by the community of PCK practitioners. It is knowledge formally obtained from formal teacher training programs, formally documented publications regarding the debates, discussions, and comprehension of PCK (Makhechane & Mavhunga, 2021). Furthermore, cPCK is the knowledge held collectively by the community of practice believed to be effective knowledge for transforming content knowledge in ways that the learners will understand. The example of collective PCK is the TSPCK maps (Park & Chen, 2012) and rubrics (Miheso & Mavhunga, 2020) for capturing the quality of eTSPCK. The cPCK realm knowledge ranges in grain size PCK from Discipline-Specific PCK to Topic Specific-PCK and Concept Specific-PCK (Carlson et al., 2019).

Discipline specific PCK is concerned with scientific methods and arguments of a specific subject matter discipline (Carlson et al., 2019). TSPCK considers the understanding of effective ways to teach a specific topic in a subject matter. This can range from knowing students' prior conceptions, effective representation, and instructional methods for teaching that topic (Makhechane & Mavhunga, 2021). The last grain size PCK is concept specific, which considers specific methods and strategies for transforming specific concepts in ways that learners will understand (Carlson et al., 2019). The focus of the theoretical framework implied by this study is the grain size cPCK that is Topic Specific PCK.

Personal PCK (pPCK)

This is a second realm of PCK, it draws from a set of skills that an individual teacher has acquired from their own classroom practices and learning experiences like the formal studying of cPCK from a university module or course and in published journals. Personal PCK (pPCK) is influenced by teachers' individual beliefs and attitude in the teaching of science, values, and the extent of cPCK internalized comprehension (Carlson et al., 2019). In short, pPCK is teacher’s individual pedagogical knowledge guided by previous personal experiences obtained from different sources and contexts (Carlson et al., 2019). Thus, pPCK is observable in individual’s teachers planning to teach which is considered as planned PCK (plPCK). On the other hand, pPCK that a teacher demonstrates in an actual classroom teaching setting is enacted PCK (ePCK). This realm of PCK can also be demonstrated in grain sized PCK, like plTSPCK and eTSPCK.

Enacted PCK (ePCK)

This realm of PCK focuses on the actual practice of science teaching in terms of instruction, implementing the teaching plan, reflecting on particular teaching instructions and the outcomes of the learners (Akinyemi & Mavhunga, 2021; Carlson et al., 2019). The ePCK is concerned with knowledge and skills that different teachers use to assist students in a certain context to acquire knowledge of a specific discipline, topic, or concept (Carlson et al., 2019). The ePCK realm focuses on the practices of PCK in action, observed when a teacher engages in direct teaching with the learners to achieve a specific learning goal or outcome from a group of learners situated in a specific learning context. In other words, it is what the teachers do or practice in an actual classroom-teaching context.

2.13.3 Topic Specific Pedagogical Knowledge (TSPCK)

As stated earlier in this study, the focus was PCK that is topic specific. Mavhunga (2019) introduced a simplified RCM of PCK that clearly shows the positioning of TSPCK within the new RCM of PCK. The following Figure 2.1 shows the simplified diagram for the new PCK RCM and the position of TSPCK as one of grain size PCK in the simplified model.

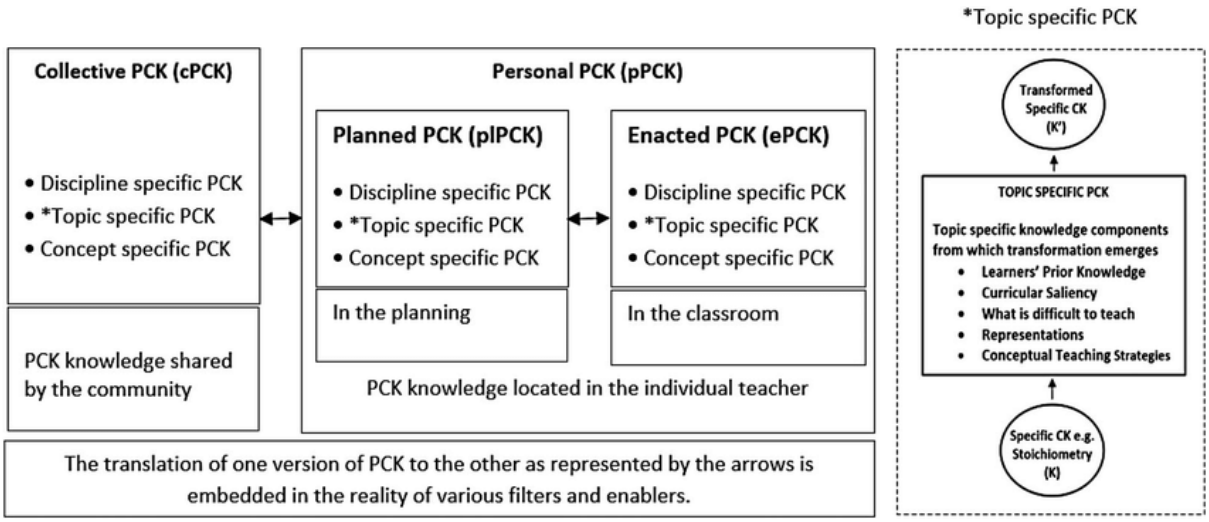


Figure 2.1: Simplified positioning of TSPCK in the new Refined Consensus Model of PCK (Mavhunga & van der Merewe, 2020, p. 67)

TSPCK began when Shulman (1986) articulated that the strategies used to implement pedagogical knowledge are content specific. Geddis (1993) later elaborated the knowledge that the teacher must have to be able to teach content knowledge in their subject of specialisations.

Thus, Geddis and Wood (1997) introduced a transformative PCK model, which presented five different components namely, learner prior knowledge, subject matter related representations, instructional strategies, curriculum materials and curriculum saliency. Mavhunga (2012) articulated that this proposed PCK model was of TSPCK nature. Thus, Mavhunga and Rollnick (2013) developed a model of TSPCK, which has been widely used and considered as a valid PCK even in the new RCM (de Sá Ibraim & Justi, 2021).

The following **Figure 2.2** shows the TSPCK model in more detail according to Mavhunga and Rollnick (2013).

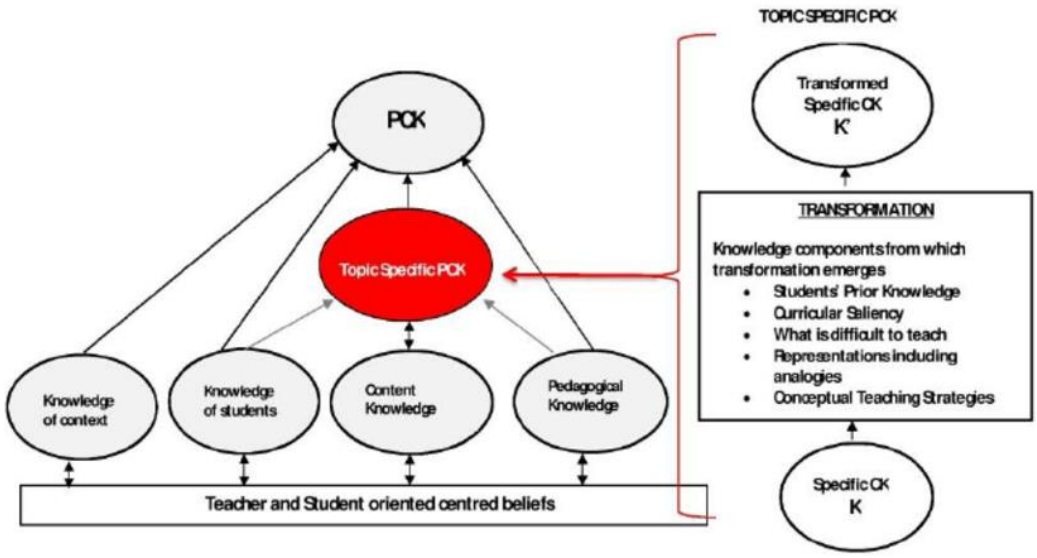


Figure 2.2: TSPCK model by Mavhunga and Rollnick (2013, p. 115)

The TSPCK model shows five (5) components that a teacher needs to consider in reasoning to teach a specific content knowledge in ways that will transform it for the learners. The above **Figure 2.2** model of TSPCK shows these components and portrays the link between TSPCK acquired in planning and TSPCK demonstrated through enactment in the classroom (Mavhunga & Rollnick, 2013). The first major component of TSPCK is Learner Prior Knowledge (LP). This component of TSPCK considers the knowledge that the learners already know before they are taught a specific topic.

Henceforth, Jones and Brader-Araje (2002) argued that learners do not come to school as empty vessels. Thus, learners come with experiences and knowledge that includes either formal school knowledge acquired through previous formal lessons or knowledge acquired from their

everyday life experiences depending on the context they come from. This can be either accurate knowledge about a scientific topic or inaccurate knowledge with misconceptions held by the learners for a specific scientific topic (Akinyemi & Mavhunga, 2021). The second major component is Curricular Saliency (CS), which is concerned with learning of numerous topics in relation to the whole curriculum. Curricular saliency considers the specific intentions of what the teacher intends for the learners to know. This includes knowing the most important concepts in a topic and knowing prior knowledge, needed to learn those concepts and the sequencing of how they can be best taught for effective learning (Akinyemi & Mavhunga, 2021).

The third component is what makes a topic difficult to teach (WD). This refers to the awareness of complex or difficult concepts in a topic in order for the teacher to come up with creative ways of breaking difficult concepts or ideas into easily accessible knowledge (Akinyemi & Mavhunga, 2021). The fourth component is learner Representations (RP), this includes analogies, visual illustrations, models, simulations which are used to assist the learners in attaining conceptual understanding in a specific topic (Akinyemi & Mavhunga, 2021). This component can be visualized at three (3) different levels, namely, microscopic, macroscopic, and symbolic (Talanquer, 2011).

The last component is Conceptual Teaching Strategies (CTS), which refers to instructional strategies that the teacher uses to help learners understand specific concepts within a topic. This includes unpacking important concepts, addressing misconceptions, using representation to help learners visualize certain knowledge and emphasizing specific concepts or ideas in a topic. This component also involves strategies that a teacher uses to address specific difficulties in a topic (Akinyemi & Mavhunga, 2021). Thus, the use of five (5) TSPCK components interactively in a complimentary manner leads to the transformation of content knowledge within a specific topic (Mavhunga, 2020).

CHAPTER 3: RESEARCH METHODOLOGY

Abstract

In the previous Chapter, I reviewed the literature and theoretical framework in relation to this study. In this Chapter, the focus is on discussing the research design employed in this study to investigate the quality of TSPCK visible in enactment of PST's self-recorded digital videos. In doing so this Chapter will discuss the research paradigm, approach, design, data collection methods, data analysis method, sampling, context, participants, trustworthiness, and ethics of this study.

3.1 Restating the main aim of the study

The primary objective and purpose of this study were to examine the nature of TSPCK displayed in the Chemistry Methodology class for PST's self-developed teaching videos on the topic of Chemical Equilibrium. Hence, the construct of traditional TSPCK was a guiding framework of this study. In doing so, this study asks the main question of, what is the nature and quality of PSTs' TSPCK displayed in teacher, self-recorded teaching videos on the topic of Chemical Equilibrium?

3.2. Research paradigm

According to Hatch (2002), researchers are situated in a specific paradigm, which guides their lens of analysis. This is so because a paradigm is a body of knowledge made up of beliefs, values and theories concerned with "how the world is organized, what we really know about it, and how we could know it" (Hatch, 2002, p.11). A research paradigm induces the study's epistemological and ontological viewpoint. Consequently, it is vital to select a paradigm that reflects the researcher's philosophical and ontological standpoint on the topic being researched (Zulu, 2018). Likewise, I positioned this study in the paradigm of interpretivism, which holds the view that "human affairs simply cannot be studied with the scientific methods used to study the natural world" (Gage, 1989).

As a result, the philosophical research methodology of interpretivists seek to gain insight from research participant's point of view, rather than attempting to predict how human beings act, behave, think and perceive things for meaning making (Alharahsheh & Pius, 2020). Hence,

TSPCK is teacher professional knowledge that individual teachers hold for transforming a specific topic in ways that will make learners easily comprehend it. The nature of TSPCK is tacit and personal according to individual teachers, as different teachers' reason in different ways and teach using different teaching strategies (Carlson & Daehler, 2019). The interpretivist paradigm is prone to qualitative studies, hence it is more suitable for investigating PSTs quality of TSPCK as it sought to gain insight into individual PSTs' personal TSPCK used to teach the topic of Chemical Equilibrium. Thus, PSTs quality of plTSPCK in their lesson plan and eTSPCK in their digital videos, were mined for TSPCK episodes. The PSTs also wrote reflections concerning teaching in the self-recorded digital video.

3.3 Research design

Research design is a methodology for identifying a precise process and methods that the research will follow to ensure validity and accuracy that will meet the study's objectives (Creswell, 2014). This study utilised a qualitative case study, which is a type of research design that is used in studies that seek to evaluate an event, activity, process, or individuals. A case study research design focuses on acquiring insight and in-depth understanding in the analysis of a specific case of a certain context (Creswell, 2014). Gerring (2004) argued that case study research design "is best defined as an intense study of a single unit with the goal of generalizing across larger sets of units." (Gerring, 2004, p. 341).

On the other hand, Rule and Vaughn characterize case study as "empirical investigation into a contemporary phenomenon inside a real-life environment, especially when the boundaries between phenomenon and context are not readily visible" (Rule & John, 2011, p. 4). Thus, Gerring (2004); Rule and John (2011) have a common understanding or view in the definition of a case study that compliments each other, as they are both describing case study as context-based study that attempts to gain deep insight on a researched phenomenon or participants.

As a result, case study research design is a suitable research design for this study as it explained the quality of TSPCK imparted by an intervention in a specific context, the final year PSTs at the Wits School of Education. This was an exploratory study, to gain depth understanding on the quality of TSPCK enactment by PSTs in digital pre-recorded videos. In doing so, three (3) PSTs were selected as participants of this study. The quality of their TSPCK before and after intervention were analysed both planned TSPCK (plTSPCK) and enacted TSPCK (eTSPCK) in a digital platform of videos. These pre-service teachers underwent an intervention program

where the quality of their plTSPCK and eTSPCK on a digital platform was analysed and discussed. This provided a deeper understanding of the quality of plTSPCK and enacted in the video digital platform for this specific group of PSTs.

3.4. Research approach

According to Creswell "research approaches are plans and procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation" (Creswell, 2014, p. 3). Consequently, there are three major types of research approaches in educational research namely, quantitative, qualitative, and mixed methods approach. (Creswell, 2012; McMillan, 2012).

Quantitative research approach deals with large samples and measuring of data using statistical techniques for analysis. In addition, the quantitative research approach seeks to make large, generalized claims in the large scale of people or researched phenomena (Drew et al., 2007). In contrast, qualitative research approach is concerned with detailed descriptions and explanations of a small number of participants that are rich in data. Hence, qualitative research investigates and interprets data in depth obtained from small number of people or data as to gain insight in a particular researched phenomenon of specific context (Drew et al., 2007). On the other hand, mixed methods involve the mixture of both quantitative and qualitative research approaches; it involves both detailed descriptions supported by statistical techniques and quantitative measurements (Drew et al., 2007).

Consequently, the research method of this study was a qualitative study as this study sought to gain insight on reasoning that leads to the portrayed quality of TSPCK in lesson plans for digital lessons. Furthermore, the study sought to understand the quality of plTSPCK translating into eTSPCK in the digital video. Subsequently, this study used thoroughly detailed descriptions of interpretations to analyse the collected data using TSPCK maps and rubrics. To gain deep understanding of insight provided by pre-service teachers at the Wits School of Education, this study used a small number of participants rich in data to understand their quality of TSPCK in digital teaching videos.

3.5 Research sampling

Alvi (2016) describes two types of groups when conducting a research study, namely population and sample. The population of a study is the large group of people that meets criteria

or characteristics for being in that research study. On the other hand, sample is a smaller group extracted from the population that meets the purpose and assessment criteria of the researcher conducting the study (Alvi, 2016). The sampling is divided into two probability sampling and non-probability sampling. Probability sampling is used for a statistical study or quantitative study, while non-probability sampling is for qualitative study or non-statistical study (Ritchie et al., 2003). This study adopted a purposeful non-probability sampling where participants were selected based on deliberate subjective judgement of the researcher, such as PSTs in their 4th year of study who were able to produce functional self-recorded teaching videos. This was for the purpose of selecting participants allowing detailed exploration and understanding of that particular group of people (Alvi, 2016; Ritchie et al., 2003).

As a result, the initial targeted sample of this study was the class of 27 PSTs enrolled in the Chemistry Methodology course at Wits School of Education (WSoE). This sample was targeted mainly because the Chemistry Methodology course focuses on developing PSTs TSPCK, hence all the PSTs in this class were by default an appropriate sample for this study. However, in the PSTs who gave consent to participate in this study, further selections of the data to be analysed in this study were made. Thus, only three PSTs were selected for analysis of this study. This was because firstly, the submitted pre-recorded videos were first evaluated for video functionality to determine whether one can follow through the content presented in the video with no error that stops the video. This process eliminated several PSTs videos submitted for this study.

A second, criteria that was considered was based on Shulman (1987) principle that teachers must have content knowledge before being able to transform it to their learners, which means a teacher cannot teach what they do not know. This further decreased the number of usable videos as many PSTs lacked baseline content knowledge in the topic of Chemical Equilibrium, resulting in no identifiable TSPCK episodes in their videos. Furthermore, some PSTs only submitted YouTube videos which were also further eliminated in this study. Thus, in the remaining videos only three PSTs videos were selected.

These digital pre-recorded teaching videos that were chosen then matched with their respective lesson plans to understand the thoughts and intentions that guided their teaching practices in the digital recorded video lessons.

3.6 TSPCK intervention program

3.6.1 Intervention Program Process

The intervention took place in a Chemistry Methodology course for final year PSTs. The emphasis was on the Chemical Equilibrium topic because of its perceived difficulties in teaching and learning (Makhechane & Mavhunga, 2021). The intervention took place over the course of 8 weeks, with three (3) hour sessions per week. Each week's three (3) hour session was broken down into two separate school formal periods; 1 hour was a single period early in the week. The 2 hours was a double period later in the week.

The 1-hour period, early in the week, was used to introduce the components of TSPCK e.g., Learner Prior knowledge component and unpacking the component to PSTs. The second period, which is the double period later in the week, was used for the development of competence in practical application of the learnt knowledge within the topic of Chemical Equilibrium. The nature of the class in the double period was teacher-learner interactional tutorial class approach. Furthermore, there were constant discussions in class groups about the application of the learnt component. For example, following the learning of representation as a TSPCK component, the tutorial class will focus on Chemical Equilibrium related representations.

The PSTs were taught about all five (5) TSPCK components and how they are visible in lesson plans. Furthermore, PSTs were briefly taught about reflections-for-action and reflection-in-action as one of constructive tools for teacher professional development that are mostly productive in platforms like videos (Suh et al., 2021). There were also tutorials of digital video editing using *openshot* software to help them create functional simple pre-recorded videos. The following **Table 1** shows a summary of the conducted intervention program in this study.

Table 1: Summary of the TSPCK intervention program

Week/period	TSPCK components	TSPCK intervention activity	Content knowledge focus
Week 1/ period 1 and 2	Administering TSPCK pre-intervention tasks	Introducing the research study, ethics and beginning tasking participants in designing lesson plans and digital videos with reflections.	Evaluating PST's prior knowledge before the intervention.
Week 2/ period 1 and 2	Learner Prior knowledge	Identifying common misconceptions in the topic of Chemical Equilibrium.	Facilitating discussion for identifying misconceptions related to Chemical Equilibrium e.g., there is no reaction occurring at Equilibrium
Week 3/ period 1 and 2	Curricular saliency	Conducting discussions based on the significance of identifying big ideas and subordinate's concepts in the topic of Chemical Equilibrium.	Identifying big ideas in Chemical Equilibrium e.g., The dynamic nature of Chemical Equilibrium.
Week 4/ period 1 and 2	What is difficult to teach	This session focused on identifying difficult concepts and comprehending what makes them difficult to comprehend or teach. There were extensive explanations and discussions with PSTs regarding the fact that this component is not to be confused with merely misunderstood concepts, but rather concepts that are difficult to explain to learners so that they can comprehend them.	The discussion of what is difficult to teach were things like the idea of dynamic nature of Chemical Equilibrium.
Week 5/ period 1 and 2	Representations	Different levels of representation were discussed namely, micro, sub-micro, macro, sub-macro, and symbolic level with emphasise on the use of this level of representation for effective teaching.	Showing multiple levels of representation. E.g., symbolic, microscopic and macroscopic levels of representation.
Week 6/ period 1 and 2	Conceptual Teaching strategies	This session unpacked different instructional methods, using interaction of other TSPCK components.	Examples of conceptual instructional methods was conceptual explanations and

			unpacking of Chemical Equilibrium concepts.
Week 7/ period 1 and 2	Basic video editing skills using *openshot* software.	Tutorials of how to use *openshot* video editing software.	Examples of simple videos designed with *openshot*.
Week 8/ period 1 and 2	Administering TSPCK post-intervention tasks.	Collecting TSPCK post-intervention pre-recorded digital videos and lesson plans.	

In the above **Table 1** of the TSPCK intervention program there was an emphasis on complementary TSPCK component interaction as a significant aspect influencing the quality of TSPCK displayed in plTSPCK or in eTSPCK.

3.6.2 TSPCK Post-intervention

After the above intervention, PSTs were asked to create new lesson plans and design new self-recorded teaching videos with reflection reports that they had to submit after the school practicum that they always go through every year from their 1st of study. They were expected to implement the learnt skills and competencies towards the designing of their new lesson plans and self-recorded videos. They were also encouraged to use the videos in their teaching experience sessions, to help them with their reflection of how effective their videos are. This data was collected and analysed in terms of the quality of visible TSPCK episodes in their lesson plans and self-recorded videos.

3.7 Collection of data

A group of 27 PSTs, enrolled for a Chemistry Methodology course, participated in this study. These PSTs willingly gave consent to participate in this study and designed lesson plans to teach Chemical Equilibrium in self-recorded videos. Before the intervention they were told to design lesson plan using a provided TSPCK template, to help guide their reasoning and teaching practices in the self-recorded video. Following that, they were tasked to create self-recorded teaching videos with any choice of a video editing software. However, *openshot* video editing software was recommended to the PSTs as it is a user-friendly software. This was before the PSTs were engaged with any formal contact session of TSPCK and video tutorials.

Consequently, they were given exactly seven (7) days including the weekends to plan a lesson that is a maximum of 15 minutes to teach the topic of Chemical Equilibrium. Thus, the collected data involved self-recorded videos that PSTs designed, and lesson plans that they also designed to guide their teaching in a video. The collected lesson plans were analysed using Mavhunga and Rollnick (2013) plTSPCK rubric to evaluate the quality of episodes identified in the lesson plans. Digital videos were analysed for the quality of eTSPCK, using Mavhunga and Miheso (2021) rubric.

The collected data involved 27 PSTs lesson plans and self-recorded videos. This data was subjected to purposeful sampling process and further reduced to three PSTs using the purposeful sampling method described in this Chapter. To reach a conclusion about the quality of PSTs enacted TSPCK in digital teaching videos, the videos were watched several times and transcribed word for word. Furthermore, TSPCK maps original from Park and Chen (2012) that targeted identified episodes were drawn. These episodes were then subjected to Cohen's Kappa inter-rater reliability evaluation according to Warren (2015). This is so because inter-rater reliability is a tool used to assess the agreement of the data rated by different raters. Flight and Julious (2015) provided a table of ratings to understand a good agreement score in rated data. The following table was taken from Flight and Julious (2015).

Table 2: Interpretation of the Kappa statistics (Flight & Julious, 2015, p. 2)

Kappa	Agreement
<0.20	Poor
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Good
0.81 – 1.00	Very Good

Table 2 shows the level of agreement depending on the score that is calculated between the raters, ranging from *'poor'* to '*very good'*. Thus, a rating of 0.2 or 20% is considered as poor, while the rating of 0.81 or 81% is a very good agreement score between the raters of specific data sets. Hence, in this study two TSPCK expert raters were appointed and I was the first rater as a researcher. The two appointed raters were referred to as experts because they have 2 – 3 years' experience of teaching and researching in the field of TSPCK and PhD holders of this

field. These two experts separately watched the videos and indicated their agreements and disagreements in the proposed episodes of TSPCK maps. Disagreements were resolved through discussion until a point of consensus agreement was reached. This allowed confirmation and validity of the proposed eTSPCK episodes and their quality in this study.

After the intervention program the same three PSTs designed new lesson plans and self-recorded videos. In addition to the post TSPCK intervention they were asked to draft less than one page reflection reports on their experience of teaching through self-recorded videos. This new data was collected and analysed in this study. The post intervention lesson plans and self-recorded videos were also again transcribed, analysed, and subjected to inter-rater reliability for the validity of TSPCK episodes. In summary the collected data included two sets of lesson plans and self-recorded videos for pre and post TSPCK intervention.

3.8 Research instrument

3.8.1 TSPCK in planning instrument

This study focused on the quality of TSPCK translating from plTSPCK to eTSPCK in a self-recorded video. According to Carlson et al. (2019) there is a difference between PCK manifesting in planning and in enactment. Consequently, different rubrics were used to measure TSPCK in planning and TSPCK in enactment. Hence, the following rubric, labelled **Table 3** was adapted from Mavhunga and Rollnick (2013).

Table 3: Rubric for TSPCK in planning (Mavhunga & Rollnick, 2013, p. 119)

Rubric for analysing TSPCK

	(1)Limited	(2) Basic	(3) Developing	(4)Exemplary
Curriculum Saliency	• Identified concepts are a mix of Big Ideas and subordinate ideas • Sequencing no value due to mixed concepts	• 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.	• Identifies at least 3 Big Ideas • Subordinate concepts correctly identified for all Big Ideas • Provides logical sequence	• 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
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.
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
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

The above **Table 3** was used as an assessment criterion for PSTs Chemical Equilibrium plTSPCK visible in their lesson plans. The rubric uses a four-point scale grading system, with one (1) being '*limited'*, two (2) representing *'basic'*, three (3) representing '*developing'*, and four (4) signifying '*exemplary'* plTSPCK quality level. These four-point scale criteria are based on the stated description of TSPCK components per displayed grading of TSPCK as seen in the above table. The criteria for each TSPCK component were not altered because they are applicable to the topic of Chemical Equilibrium under investigation in this study. **Table 3** primary unit of analysis for the category of specific plTSPCK quality is the complementary interaction between TSPCK components per individual episode.

3.8.2 TSPCK in enactment instrument

As indicated earlier, that the visibility of TSPCK in planning is different from TSPCK visible in enactment in accordance with Carlson et al. (2019). Consequently, the instrument used in this study to evaluate the quality of eTSPCK is a following rubric by Mavhunga and Miheso (2021).

Table 3.1: TSPCK in enactment (Mavhunga & Miheso, 2021, p. 13)

Simple	Proficient	Sophisticated
-Evidence of two different TSPCK components interacting evidently and distinguishably in a specific teaching segment -The components interactions maybe interwoven or have a linear sequence structure format	-Evidence of three different TSPCK components interacting evidently and distinguishably in a specific teaching segment. -One of the components maybe repeated in the same TSPCK episode bringing-in additional depth in teacher explanations. -The components interactions maybe totally interwoven or a combination of an interwoven structure with a linear link to another different component.	-Evidence of four different TSPCK components interacting evidently and distinguishably in a specific teaching segment - One of the components maybe repeated in a manner that brings different levels of sophistication (e.g. representations used at all three levels: macro, symbolic and sub-microscopic levels) - The components interactions maybe totally interwoven or a combination of an interwoven structure with a linear link to another different component, or a set of interwoven multiple components.

The above **Table 3.1** is a simplified version of TSPCK in enactment as seen in Mavhunga and Miheso (2021). This eTSPCK rubric was used to identify TSPCK episodes, according to '*simple*', *'proficient'*, and '*sophisticated'* quality of eTSPCK. The unit of analysis of this rubric is the number of present different TSPCK components, interacting together in a complimentary manner per identified episode. For example, if there are visible CS and RP components of TSPCK, the episode will be in *'simple'* quality of eTSPCK. As a result, in further emphasis the core unit of analysis is the complementary interactions of various TSPCK components in that specific episode.

3.9 Pre-recorded video observation

Pre-recorded video observations are a type of research observation in which the researcher uses previously recorded recordings to gain a better understanding of an event that has already occurred. Observations allows the researcher to describe real situations using the five senses, resulting in a documented and clear depiction of the situation under investigation. Thus, this study used digital video lessons in the topic of Chemical Equilibrium designed by PSTs for

teaching grade 12 learners, to mine episodes that are rich in TSPCK as to understand the quality of TSPCK portrayed by PSTs in their Chemical Equilibrium self-recorded teaching videos.

3.10 Data analysis

3.10.1 TSPCK in planning analysis

As highlighted above, the rubric used for analysing TSPCK in planning is Mavhunga and Rollnick (2013), which uses four-point scale for each plTSPCK. The four (4) point scale ranges from *(1) limited, (2) basic, (3) developing* and *(4) exemplary* which shows the quality of plTSPCK. The PSTs lesson plans were analysed according to this rubric. The TSPCK components were first identified in a specific segment then arranged in the sequence of emergence through TSPCK maps. Following that, the episode was rated in terms of the quality of portrayed eTSPCK. For example, in a situation where there is identification of TSPCK components that emerged in the sequence of Learner Prior Knowledge (LP), Curricular Saliency (CS) and Representations (RP) resulting in the drawing of the following TSPCK map as shown in **Figure 3**.

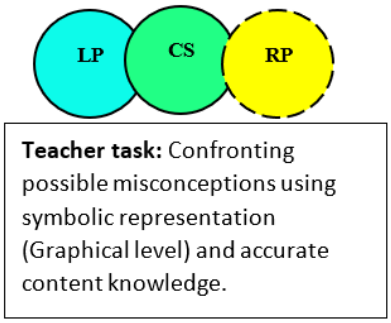


Figure 3: Example of plTSPCK episode

Consequently, the above **Figure 3**, shows an episode of plTSPCK with component interaction of Learner prior knowledge (LP), Curricular saliency (CS), and Representation (RP). In **Figure 3**, these components of TSPCK are interacting in a complimentary manner. Consequently, based on the above **Table 3.1** rubric of plTSPCK by Mavhunga and Rollnick (2013), this episode shows *'developing'* quality level of plTSPCK. Hence, this is the manner in which the plTSPCK episodes were analysed in this research study.

Furthermore, this was done for the data of both pre-intervention and post-intervention lesson plans. Also, the lesson plan assisted towards understanding the intended TSPCK in the self-

recorded teaching videos. The reflections of the post intervention were analysed for PSTs experience in teaching the topic of Chemical Equilibrium on self-recorded videos.

3.10.2 Enacted TSPCK analysis

As highlighted in the above section of instruments used in this study, the rubric used to analyse eTSPCK by Mavhunga and Miheso (2021) as seen in **Table 3.1**. The procedure of analysis that was followed was first watching the video showing evidenced of eTSPCK. These videos were then screenshotted for visuals that corresponded to the transcribed explanation of PSTs, which were marked using distinct colour codes for TSPCK components visible in those explanations. TSPCK maps were then drawn in the sequence of emergence based on that specific identified episode. According to Mavhunga (2020), eTSPCK quality is identified as the point in time where there were clear visible two or more TSPCK components interactions. These specific rich TSPCK component interactions are referred to as TSPCK episodes. This was then rated according to '*simple', 'proficiency'* or *'sophisticated'* quality of eTSPCK depending on that specific episode.

Thus, the rating of the quality of eTSPCK depends on complimentary interaction of the identified different TSPCK components. For example, two components interacting in a complimentary manner shows '*simple'* eTSPCK quality, while three TSPCK components interacting in a complimentary manner shows '*proficient'* quality of eTSPCK. Lastly, four (4) or more TSPCK components interacting in a complementary manner shows a *'sophisticated'* eTSPCK quality, which is the highest level of enactment.

Hence, an enacted lesson was analysed to be '*simple', 'proficient',* and '*sophisticated'* based on the TSPCK episodes visible in Chemical Equilibrium digital teaching videos. To show the TSPCK component interactions, TSPCK maps introduced by Park and Chen (2012) were used to clearly illustrate the exact components that were interacting in a specific episode in the order of their emergence. The identified TSPCK episodes were allocated to specific quality of eTSPCK according to the rubric for eTSPCK by Mavhunga and Miheso (2021).

For example, **Figure 3.1** shows an episode of eTSPCK.

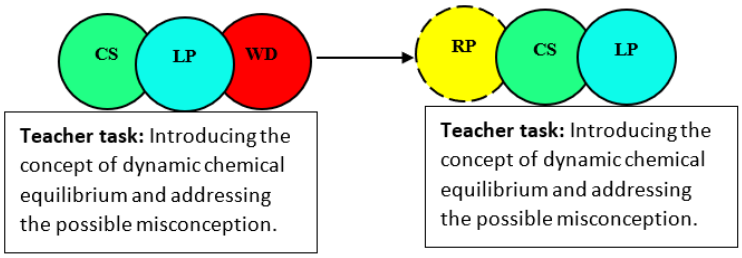


Figure 3.1: Example of eTSPCK

The above episode shows the complementary interaction of TSPCK components. This episode shows two kinds of interactions, the clustering and linear complimentary interaction. Thus, this episode consists of two other TSPCK episodes that make up the main episode of eTSPCK to transform explanations. Thus, this episode shows *'proficient'* quality of eTSPCK according to Mavhunga and Miheso (2021) rubric. Consequently, all identified episodes of TSPCK in enactment for both pre and post TSPCK intervention were analysed in this way.

3.11. Validity and Reliability

Suter (2011) argues that the quality of a qualitative study lies in its ability to be credible. Similarly, Merriam and Tisdell (2016) stated that internal validity or credibility is a significant factor towards the strength of a qualitative study. Validity refers to the study's integrity, the application of intended methods and precision of the findings in a way that truly and accurately reflects the facts of the collected data (Noble & Smith, 2015). On the other hand, reliability refers to the consistency within the used tools and methods for data analysis. Thus, several studies have implemented the concept of using TSPCK maps in identifying TSPCK episodes and rate the quality of TSPCK in those episodes. As a result, the use of TSPCK maps and rubrics for evaluating plTSPCK and eTSPCK in this study is based on what has been proven and validated in the field of TSPCK (Carlson et al., 2019; Mavhunga & Van der Merwe, 2021; Park & Chen, 2012;). Furthermore, the use of rubrics for both eTSPCK and plTSPCK has been validated as valid tools for measuring the quality of plTSPCK (Mavhunga & Miheso, 2021; Rollnick & Mavhunga, 2014;).

Credibility, transferability, dependability, and conformability are believed to be four components of trustworthiness, which refers to the quality of both results and data (Letts et al., 2007). To ensure reliability or trustworthiness, this study used TSPCK maps and calculated

inter-rater reliability using Cohen's Kappa coefficient with two other expert raters in confirming identified components in an episode of TSPCK. There were discussions in resolving any cases of different view in the identified episodes. This concluded the agreement of the identified TSPCK episodes.

The intervention program of this study was conducted under the supervision of university-qualified lecturers who validated all the activities that took place in the Chemistry methodology class. Prior to conducting the study, I attended a proposal defence presentation where I first presented my proposed study, amongst university experts in the field. The study was accepted with critique, which I took into consideration and implemented before conducting the study.

3.12 Ethical consideration

Ethical consideration is one of the significant aspects when conducting a research study. Gajjar (2013) argues that ethical consideration is more than just the morality of the study, but it is about ensuring the respect of human rights, values, and to protect people from any harm due to scientific study. Furthermore, Gajjar (2013) defines ethics as a strategy, procedure, or point of view for deciding how to act and analyse complex problems and situations. Consequently, the University of the Witwatersrand ethics committee for non-medical research studies granted ethical clearance to conduct this study. Hence, all participants of this study were protected from exposure of their personal details. In a way that none of their personal details were mentioned at any point in reporting the findings of this study.

The consent form was given to the participants, which described what the study was about, how it would help them and the researcher, and that their personal information, including names and student numbers, would be kept completely confidential. Furthermore, they were assured that in no circumstances would their faces be displayed in this study. In a situation where their face appeared, it was cropped out or for protecting the privacy of the participating PSTs. Furthermore, no real name of the participants was mentioned, in a case where I had to refer to a specific PST a pseudonym was used. Participating PSTs also gave their consent to use their videos for research purposes and their reflection reports.

CHAPTER 4: DATA PRESENTATION AND ANALYSIS

Abstract

In the previous chapter I provided an overview of the research design used in this study. I particularly gave a description of an intervention program targeting the development of TSPCK in a transitioning period between traditional classroom settings to delivering lessons in a digital format as digital video lessons. In this chapter I am providing a qualitative analysis and the findings from the work of final year pre-service teachers (PSTs) presenting the quality of planned TSPCK (plTSPCK) as seen in their lesson plans, and enacted TSPCK (eTSPCK) as seen in their self-designed digital video lessons (This chapter will be followed by a discussion of the findings).

4.1 Background Summary

The participating PSTs were exposed to a TSPCK intervention program that focused on helping them learn how to use the five different knowledge components of TSPCK interactively to transform content knowledge for learner understanding and record a video lesson to reflect their learned competences. The duration of this intervention program was eight (8) weeks, with three (3) hours of sessions per week. A particular method was adopted, where one (1) hour period was devoted at exploring one component at a time, e.g., Learner Prior Knowledge and its interaction with other components. The two (2) hour session was used for tutorials, discussions and application of that specific component being explored in that week. The importance of TSPCK components interacting in a complementary manner was emphasized as a major significant aspect that reveals the quality of portrayed planned or enacted TSPCK. There were also tutorials of video editing skills using a video editing software *openshot*, as a free and accessible resource.

As alluded in Chapter 3, the unit of analysis here is the extent of visible TSPCK component interactions. To operationalize this, a segment in the teacher task that reflected two or more complimentary interactions of TSPCK components was considered a TSPCK episodes (Mavhunga & Miheso, 2021). The identified TSPCK episode was then subjected to an in-depth qualitative analysis. The analysis process began first by identifying the TSPCK episodes by the researcher and subjected to inter-rater reliability analysis for the confirmation of the episode by two other expert raters in the field of TSPCK. These episodes were then described to provide

context of the teacher task and actions that were implemented in that episode. This was followed by a description of the TSPCK components present, how they interact with one another, and the sequence in which they emerge.

4.2. Preparation of the data for analysis.

The initial sample of the data collected was from the entire class of 27 PSTs, however the total number of participants in the analysed data for this study was three (3) PSTs. The refinement of data to three (3) PSTs began with a selection process of functional digital videos in the topic of Chemical Equilibrium. According to Shulman (1986), PCK focuses on teachers' ability to transform content knowledge for learners understanding. Hence, the first most important aspect that PCK considers is teacher's understanding of content knowledge. Likewise, Mavhunga (2016) articulated that content knowledge is a non-negotiable factor in the success of teacher's TSPCK. Consequently, baseline content knowledge in Chemical Equilibrium topic was one of the minimum requirements for the selection of digital teaching videos for this study.

Several videos submitted by PSTs were discarded due to errors and significant gaps in baseline content knowledge in Chemical Equilibrium topic. In such videos it was not possible to identify TSPCK episodes in those digital teaching videos, making it difficult to establish with any accurate response to the main research question which asks, "What is the nature and quality of PSTs' TSPCK displayed in teacher, self-recorded teaching videos on the topic of Chemical Equilibrium?" To establish the nature of TSPCK visible in preservice teachers' self-recorded digital teaching videos in Chemical Equilibrium previous studies have investigated the implementation of acquired PCK in teaching practice and in traditional classroom, (Miheso & Mavhunga, 2020) but little is known about the nature of PCK, specifically TSPCK in self-recorded video lessons as both digital content and a form of enactment close but not in actual classrooms.

Furthermore, some PSTs put together different YouTube videos and submitted as their own work with very little to no input of their own. Similarly, those videos were also eliminated in this study. Subsequently, after the above process the data chosen for this study were digital videos designed by PSTs that met minimum requirements for the theoretical framework of TSPCK in their digital videos. This demonstrated a true reflection of PSTs ability to design and teach in digital videos before the TSPCK intervention training program.

The chosen digital teaching videos were then matched with their respective lesson plans so as to understand thoughts and intentions that guided their teaching practices in the recorded video lessons. Warren and Marz (2015) stated that Cohen's Kappa coefficient for statistics is a widely used instrument for calculating agreement between different raters in a given research data. In order to ensure the reliability of the identified episodes, Cohen's Kappa coefficient was used in this research study to calculate the level of agreement in the TSPCK episodes identified between the researcher and two other expert raters, who are science teacher educators with 2-3 years' experience in teacher education, with their research using the conceptual framework of TSPCK. The results shown in **Table 4** indicate identified TSPCK episodes for Leon's lesson before the TSPCK intervention program, were obtained.

Table 4: Inter-rater calculations for Leon's TSPCK pre-intervention lesson

Keys

Rater 1:	**Researcher**
Rater 2:	Expert 1
Rater 3:	Expert 2

TSPCK Components in episodes	**Ratings**			**Calculating the agreement of the ratings**			
	Rate 1	**Rate 2**	**Rate 3**	**R1/R2**	**R1/R3**	**R2/R3**	**Agreement**
Learner Prior Knowledge (LP)	1	1	1	1,00	1,00	1,00	1,00
	0	0	0	1,00	1,00	1,00	1,00
	0	0	0	1,00	1,00	1,00	1,00
	1	1	1	1,00	1,00	1,00	1,00
Curricular Saliency (CS)	1	1	1	1,00	1,00	1,00	1,00
	0	0	0	1,00	1,00	1,00	1,00
	3	3	2	1,00	0,00	0,00	0,33
	4	4	4	1,00	1,00	1,00	1,00
What is difficult to teach (WD)	0	0	0	1,00	1,00	1,00	1,00
	0	0	0	1,00	1,00	1,00	1,00
	1	1	1	1,00	1,00	1,00	1,00
	2	1	2	0,00	1,00	0,00	0,33
Representations (RP)	1	1	1	1,00	1,00	1,00	1,00
	1	1	1	1,00	1,00	1,00	1,00
	3	3	3	1,00	1,00	1,00	1,00
	4	4	3	1,00	0,00	0,00	0,33
Conceptual teaching strategies (CTS)	0	0	0	1,00	1,00	1,00	1,00
	1	1	0	1,00	0,00	0,00	0,33
	0	0	0	1,00	1,00	1,00	1,00
	0	0	0	1,00	1,00	1,00	1,00
						Average	**0,87**

The inter-rater reliability = 0,87 or 87%

The results of the Cohen's Kappa technique cited on Warren (2015) were calculated for the level of agreement in the episodes identified on Leon's lesson before the TSPCK intervention program as seen on the above **Table 4**, Cohen's Kappa value of 0,87 or 87% was obtained. According to Flight and Julious (2015), this is a "very good" Cohen's Kappa agreement score between the raters for a particular set of data.

The highlighted areas in the above **Table 4** reveal cases where there were disagreements between raters. These disagreements were resolved through discussions until a consensus decision was established for specific concern episodes. The similar procedure was followed for Lebo and Mandy as part of participating PSTs for this study. The calculated score in the pre-intervention program for Mandy was 0,83 or 83% and for Lebo it was 0,86 or 86%. Likewise, in accordance with Flight and Julious (2015) these were very good scores. Similarly, disagreements were resolved through discussions until the raters reached the point of common agreement. The similar procedure was conducted for episodes identified after the TSPCK intervention program where the following results were calculated for Leon's TSPCK lesson, as seen on the next page.

Table 4.1: inter-rater calculations for Leon's TSPCK post-intervention lesson

Keys:

Rater 1:	**Researcher**
Rater 2:	Expert 1
Rater 3:	Expert 2

TSPCK Components in episodes	**Ratings**			**Calculating the agreement of the ratings**			
	Rate 1	**Rate 2**	**Rate 3**	**R1/R2**	**R1/R3**	**R2/R3**	**Agreement**
Learner Prior Knowledge (LP)	1	1	1	1,00	1,00	1,00	1,00
	0	0	0	1,00	1,00	1,00	1,00
	0	0	0	1,00	1,00	1,00	1,00
Curricular Saliency (CS)	1	1	1	1,00	1,00	1,00	1,00
	1	1	1	1,00	1,00	1,00	1,00
	1	1	1	1,00	1,00	1,00	1,00
What is difficult to teach (WD)	0	0	0	1,00	1,00	1,00	1,00
	1	1	1	1,00	1,00	1,00	1,00
	1	0	0	0,00	0,00	0,00	0,00
Representations (RP)	0	0	0	1,00	1,00	1,00	1,00
	1	1	1	1,00	1,00	1,00	1,00
	2	2	2	1,00	1,00	1,00	1,00
	1	1	1	1,00	1,00	1,00	1,00
Conceptual teaching strategies (CTS)	1	1	1	1,00	1,00	1,00	1,00
	2	2	2	1,00	1,00	1,00	1,00
	0	0	0	1,00	1,00	1,00	1,00
						Average	**0,94**

The inter-rater reliability = 0,94 or 94%

Table 4.1 above shows the results calculated for the level of agreement in the episodes identified for Leon's lesson after the TSPCK intervention program where Cohen's Kappa value of 0,94 or 94% was obtained, which is an excellent agreement score (Flight & Julious, 2015). The highlighted area in the above **Table 4.1** reveals a case where there was disagreement between the raters in the identified TSPCK components of the episode. Again, this was resolved through discussions until a consensus decision was established, in this case as I was the only one seeing the episode, we reached a conclusion of disregarding the proposed episode. Similarly, Lebo attained 0,92 or 92% score and Mandy attained 0,90 or 90% score. These were also excellent scores of Cohen's Kappa coefficient value (Flight & Julious, 2015). In the results for TSPCK pre-intervention program **Table 4** and TSPCK post-intervention program **Table 4.1** there is a significant difference in Cohen's Kappa scores, which indicates an increase in

level of agreement for episodes identified in the TSPCK post-intervention. Similarly, this is also the case with Lebo's and Mandy's agreement scores.

4.3. The rubrics used for analysis of TSPCK episodes

4.3.1 Rubric for the quality of TSPCK in planning

The analysis of this study begins with analysing the quality of planned TSPCK (plTSPCK) captured in PSTs lesson plans to teach in pre-recorded digital videos using the following Mavhunga and Rollnick (2013) rubric of TSPCK in planning, as indicated in Chapter 3.

Table 3: Rubric for TSPCK in planning (Mavhunga & Rollnick, 2013, p. 119)

Rubric for analysing TSPCK

	(1)Limited	(2) Basic	(3) Developing	(4)Exemplary
Curriculum Saliency	• Identified concepts are a mix of Big Ideas and subordinate ideas • Sequencing no value due to mixed concepts	• 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.	• Identifies at least 3 Big Ideas • Subordinate concepts correctly identified for all Big Ideas • Provides logical sequence	• 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
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.
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
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

Table 3 indicates what was consider as evidence of a particular TSPCK component (Mavhunga & Rollnick, 2013). It further highlights the fact that, the unit of analysis or affirmation of a TSPCK episode is through the complimentary interaction of the components rather than their mere presence.

4.3.2 Rubric for the quality of TSPCK in enactment

The second analysis in this study was conducted considering the following rubric by Mavhunga and Miheso (2021) for eTSPCK.

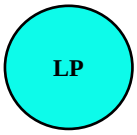
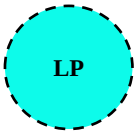
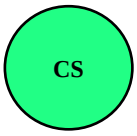
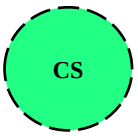
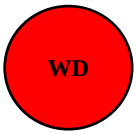
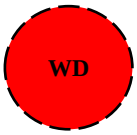
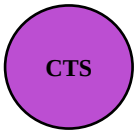
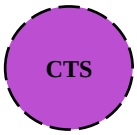
Table 3.1: TSPCK in enactment (Mavhunga & Miheso, 2021, p13)

Simple	Proficient	Sophisticated
-Evidence of two different TSPCK components interacting evidently and distinguishably in a specific teaching segment -The components interactions maybe interwoven or have a linear sequence structure format	-Evidence of three different TSPCK components interacting evidently and distinguishably in a specific teaching segment. -One of the components maybe repeated in the same TSPCK episode bringing-in additional depth in teacher explanations. -The components interactions maybe totally interwoven or a combination of an interwoven structure with a linear link to another different component.	-Evidence of four different TSPCK components interacting evidently and distinguishably in a specific teaching segment - One of the components maybe repeated in a manner that brings different levels of sophistication (e.g. representations used at all three levels: macro, symbolic and sub-microscopic levels) - The components interactions maybe totally interwoven or a combination of an interwoven structure with a linear link to another different component, or a set of interwoven multiple components.

The above table was used as a unit of analysis in determining segments that qualifies as episodes of TSPCK in the digital teaching videos. The core of evidenced segment to qualify as an episode of TSPCK lies in the complimentary interaction of the identified episode.

The following keys are used in this chapter to establish ease reference in identifying TSPCK components, showing TSPCK component interactions and their sequence of emerge in an episode.

Table 4.2: TSPCK components key indicators

TSPCK components	Strong TSPCK component	Weak TSPCK component
LP - Learner Prior Knowledge		
CS - Curricular Saliency		
RP – Representations		
WD - What is difficult to teach		
CTS - Conceptual Teaching strategy		

The above **Table 4.2** shows the keys that are used in this chapter as a method of identifying TSPCK components. As seen on the above **Table 4.2**, there are two types of circles represented, where one shows a solid circle line, and another copy showing a dotted circle line. This distinction in the above circles separates a clear strong with convincing evidence TSPCK component from a lacking implied or weak TSPCK component. This is an important distinction applied in this chapter for components in both plTSPCK (lesson plans) and eTSPCK (digital video lessons). However, a significant aspect to recall is that the quality of TSPCK is based on the extent of the interactions of the components present in the identified TSPCK episode. Therefore, the unit of analysis is the evidence of the extent of the interactions, rather than the mere presence of the TSPCK components (Mavhunga & Miheso, 2021).

4.4. Description of data analysis sequence

For each participant of the three (3) PSTs I have analysed two (2) sets of data for both pre and post TSPCK intervention. I started with the lesson plan which was analysed for the quality of plTSPCK using Mavhunga and Rollnick (2013) rubric. This was followed by an analysis of TSPCK episodes in digital videos using Mavhunga and Miheso (2021) rubric. The participating PSTs used the same TSPCK lesson plan template. Hence, the lesson plan structure for all the participating PSTs is of the same format, which starts with identifying the lesson's objectives. A summary of the most important content knowledge, considering learners' diversity and potential misconceptions during the lesson, teaching, and learning strategies, finally the proposed logical steps of presenting the lesson.

4.4.1 Analysis of Leon's Pre-intervention

i) Lesson plan

Leon's lesson targeted introduction to Chemical Equilibrium topic, the duration of the lesson was 15 minutes. The lesson plan indicated intentions to unpack and distinguish Chemical and Physical equilibrium concepts. The lesson outcomes were stipulated, and learners were expected to be able to draw basic concentration vs time graphs and recognise the equilibrium point in a graph. Leon's lesson plan proceeded with an overview of the most important content knowledge, learner prior knowledge, teaching and learning strategies and logical steps of presenting the lesson, which is similar to the lesson plan format briefly mentioned above.

Example of an identified good segment that is however not an episode of TSPCK

The following extract from Leon's lesson plan shows a segment of TSPCK components evidence in 'Section 3: summary of the most important content knowledge'.

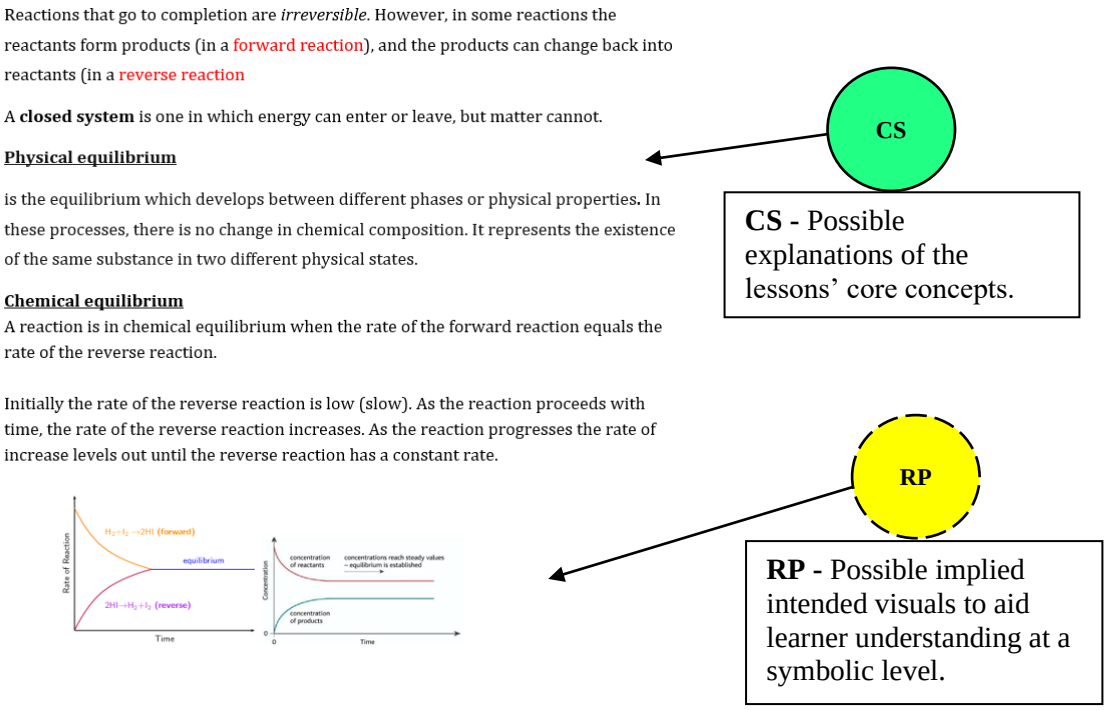


Figure 4: Leon's lesson plan extract (Pre-intervention)

Analysis of the identified components

The above extract shows evidence of two TSPCK components CS and RP. The CS component focuses on the most important content knowledge and sequencing of core concepts in relation to the whole curriculum (Akinyemi & Mavhunga, 2021). Leon demonstrated the understanding of CS in this section by summarising and sequencing concepts in a logical manner suitable for teaching e.g., the closed system and the forward and reverse reactions before unpacking Physical and Chemical Equilibrium concepts.

The CS component is portrayed as a strong CS component because of its' clearly defined intended explanations. Leon then showed RP component in terms of possible visuals at a symbolic level of graphs and chemical equations. This component appears only as a symbolic level of representation. According to Talanquer (2011) Chemistry is best understood at three levels of representations: macroscopic, microscopic, and symbolic level. Consequently, for this reason RP component is shown as dotted solid circle line which shows weak evidence of the

understanding of the applied TSPCK component. In the above components there is no clear complimentary interaction of how Leon intends to use the CS and RP components as he did not indicate, hence they appear separate and independent of each other showing the following TSPCK map.

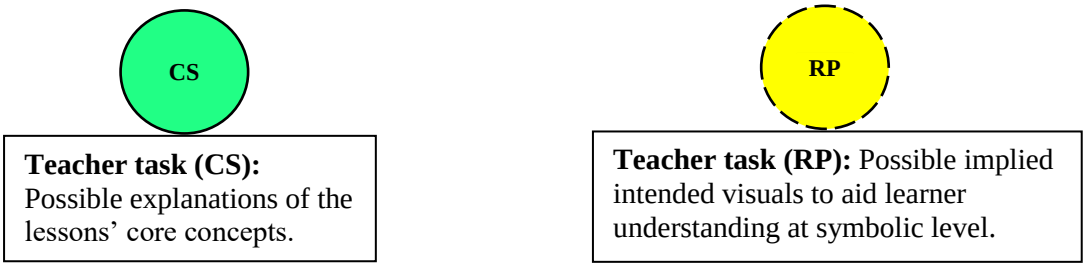


Figure 4.1: Leon's CS and RP components (plTSPCK preintervention)

Thus, this segment shows a case where there is no clear interaction of TSPCK components, which means it cannot be considered as TSPCK episode. Finally, this proves that mere presence of TSPCK components does not necessary imply an episode of TSPCK as indicated by (Mavhunga & Rollcnick, 2013; Mavhunga & Miheso, 2021). Such segments were not identified as containing TSPCK episodes thus not analysed.

ii) Identified episode of TSPCK in planning

In 'Section 4: thinking about learners' in Leon's lesson plan there was a segment of TSPCK episode, where he was explaining a possible misconception and how he plans to address it in a digital video lesson.

See the following extract,

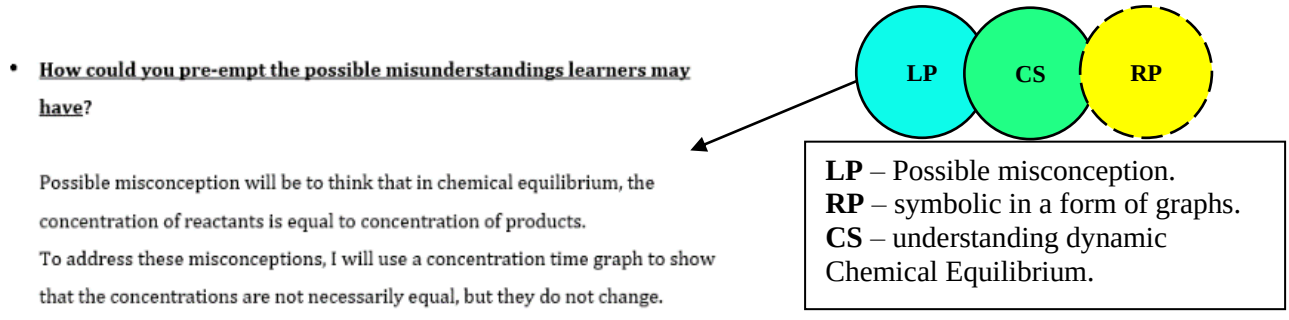


Figure 4.2: Leon's lesson plan extract (plTSPCK preintervention)

In the above extract there is evidence of three (3) different TSPCK components LP, CS and weak level of RP interacting in an interwoven manner (Mavhunga & Miheso, 2021). This is the case because Leon conveys awareness of potential misconception on this topic. This demonstrates LP component of plTSPCK that examines learners' prior assumptions, or understanding of a particular topic, including both valid conceptions and misconceptions (Akinyemi & Mavhunga, 2021). The identified misconception is of the understanding that at Equilibrium position, the concentration of reactants and products are equal. According, to Mensah and Morabe (2018) this is one of the known misconceptions that challenges learners when learning about the topic of Chemical Equilibrium. Leon showed an awareness of this misconception. In doing so, he showed TSPCK component of CS when giving accurate content knowledge which is the rates of reaction are the one that are equal not concentrations.

Furthermore, Leon articulated the intention to use graphical representations to demonstrate the state of Equilibrium position. However, this component is implied at one level of representation which is symbolic level, hence lacking other levels of representation to strengthen it, as Talanquer (2011) indicated the significance of multiple level of representation in Chemistry. As a result of clear complimentary interaction between LP, CS and RP in an interwoven manner this segment is considered as an episode of TSPCK in planning.

The following TSPCK map can be drawn from the above segment.

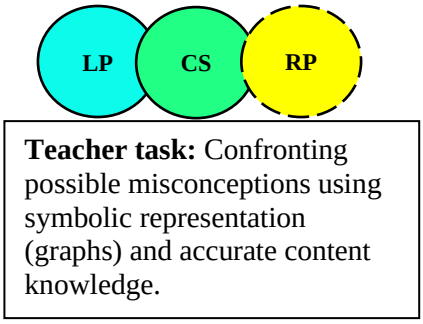


Figure 4.2.1: Leon's plTSPCK episode (Pre-intervention)

In accordance with Mavhunga and Rollnick (2013) rubric for plTSPCK, this shows, '*developing*' level of plTSPCK knowledge component. This is so because Leon first identified a misconception then further drew on two other TSPCK components to counteract the misconception. He showed CS and RP components knowledge in explaining the misconception

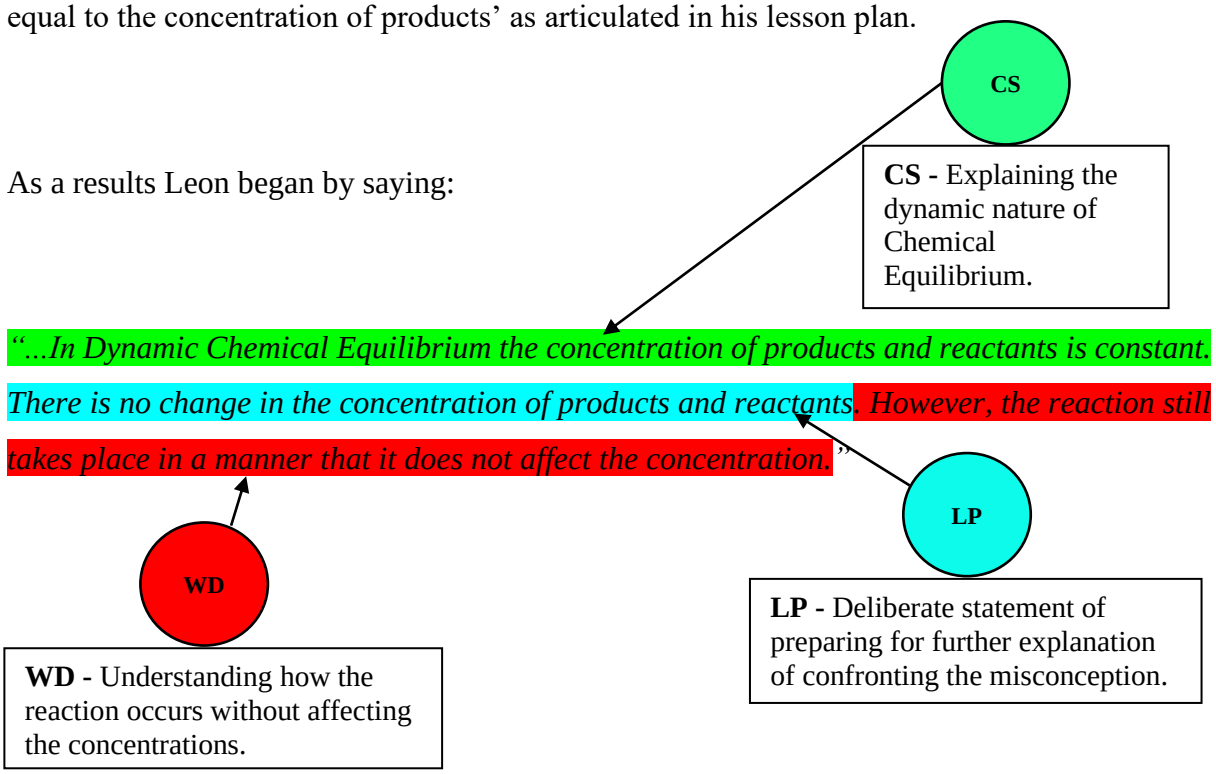
in a way that assist learners to overcome the misconception. Thus, in this episode there was complementary interaction of three TSPCK components.

iii) Pre-intervention TSPCK in enactment Leon's video lesson.

Episode: Dynamic nature of Chemical Equilibrium

This was an episode identified in enactment of a digital video lesson. In this episode Leon was explaining the concept of dynamic nature of Chemical Equilibrium. In doing so, he confronted the misconception of the understanding that 'at equilibrium the concentration of reactants is equal to the concentration of products' as articulated in his lesson plan.

As a results Leon began by saying:



In this statement Leon was demonstrating, TSPCK component of CS when explaining dynamic nature of Chemical Equilibrium and LP component in addressing the misconception. He further, showed WD component of TSPCK when stating that the reaction still happens in a manner that does not affect the concentration of the reactants and products. In this introductory segment for this episode the following map is evidenced which is seen in the following page.

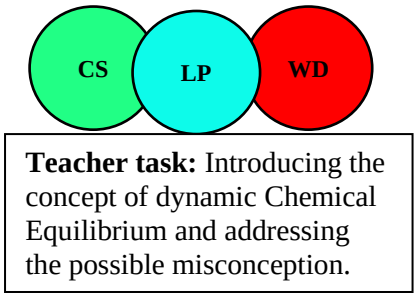


Figure 4.2.2: Leon's eTSPCK episode (pre-intervention)

The above maps show complimentary interaction of TSPCK between CS, LP and WD. This segment is in '*proficient'* enactment of TSPCK according to Mavhunga and Miheso (2021) rubric for eTSPCK. Further continuation of this episode is on the next page.

In further elaboration of the above explanations Leon showed learners the following image in his video lesson.

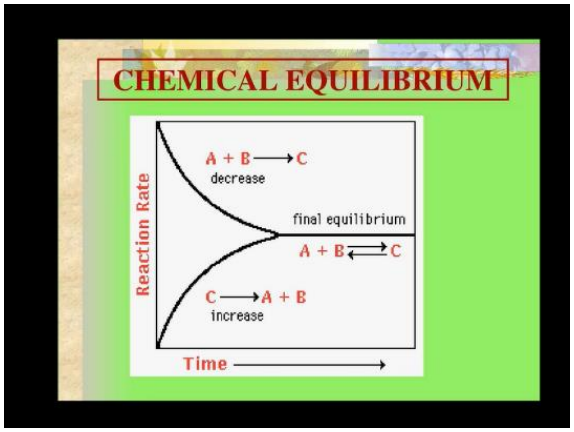


Figure 4.3: Leon's visible video slide

As the image was displayed the following explanations were given by Leon:

"Let us say we have reactants A + B = C. Now, the rate at which reactants A + B = C is equal to the rate at which C = A + B the point when we have reached the Chemical Equilibrium position. (CS, RP). In other words, we are not saying that the concentration of reactants must be equal to the concentration of products to reach Equilibrium position. (LP) But what we are saying is that the rate at which the forward reaction and the backward reaction are taking place must be equal or must be the same. (CS) So the rate at which reaction A + B = C and the rate at which reaction C = A + B must be equal. When that rate is equal, that's when we reach our chemical equilibrium position." (CS, RP).

RP - this image was used as Leon explanations using symbolic level of representation.

LP - Confronting the misconception using symbolic representations.

CS - accurate content knowledge to further disrupt the presented misconception.

In the above segment Leon explained the concept of dynamic nature of Chemical Equilibrium and puts emphasis on the explanations of accurate content knowledge to avoid the misconception of assuming that at Chemical Equilibrium position the concentration of reactants and product is the same. This was evidenced by the following TSPCK map.

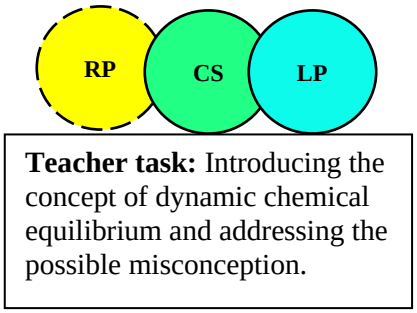


Figure 4.3.1 Leon's eTSPCK episode (preintervention)

The above TSPCK maps show complimentary interaction of TSPCK components between RP, CS and LP. This segment is in '*Proficient'* enactment of TSPCK according to Mavhunga and Miheso (2021) rubric for eTSPCK. Thus, the overall map of this episode can be drawn in the following manner, where there are clear interwoven and linear component interactions in a complimentary manner that shows clustering of TSPCK components.

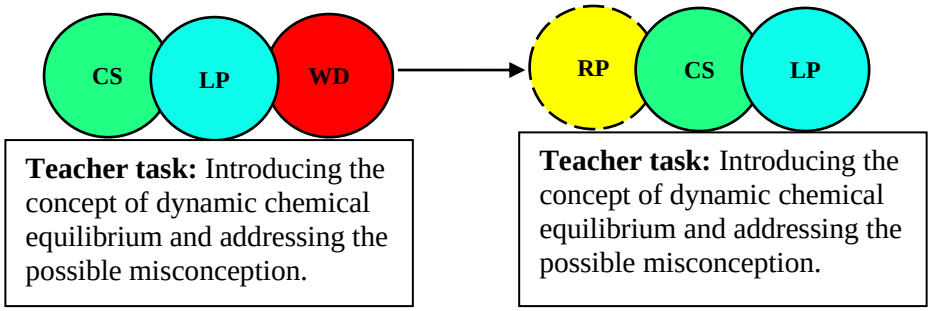


Figure 4.4: Summary of Leon's eTSPCK episode (Pre-intervention)

In the above episode, Leon used CS, RP, LP, and WD components together in bringing about transformation of content knowledge and confronting the misconception. The first portion, initially visible in **Figure 4.2.2** has three components CS, LP and WD interaction in an interwoven manner which then interact in a linear format with RP, CS and LP to form a complete map of this episode. This is because the first portion of CS, LP, and WD led to the build-up of the second interaction of weak RP, CS, and LP clustering interaction. Consequently, because there are three components per segment of this episode. According to Mavhunga and Miheso's (2021) rubric, this shows interwoven and linear interaction at *'proficient'* eTSPCK as there are also visible repetition of the same components for further transformation of explanations. The above analysis completes the pre-intervention data for Leon. Following below is the analysis of Leon's post-intervention data.

4.4.2 Leon's post-intervention data analysis

(i) Lesson plan analysis.

The TSPCK post-intervention lesson plan template was the same as the pre-intervention lesson template. Consequently, this lesson plan also followed the same structure whereby there are five major sections. The first was identifying the objectives or purpose of the lesson. The second section is the summary of the most important content knowledge, followed by thinking about the learners in relation to their diversity and possible misconceptions section. Then the 4th section of learning and teaching strategies, then the last section, which is proposed logically steps of sequencing the lesson in enactment.

Description of the lesson plan

Leon's post-intervention lesson plan focused on covering the factors that affects Chemical Equilibrium position. The duration of the lesson was estimated to be 15 minutes long. By the end of the lesson, he indicated that learners will be expected to acquire the skill of knowing which reaction is favoured when a stress is applied on a system. Where a stress in the system can be a change in concentration, temperature, and pressure. In explaining how the stress applied in the system affects the Chemical Equilibrium position Leon, unpacked the concept of Le Chatelier's principle as a guiding principle of the system's reaction during a change of concentration, temperature, or pressure. He then went into each of these factors (concentration, temperature and pressure) and explained how each of them affect the equilibrium position in greater details.

ii) Identified episode of TSPCK in planning

In 'Section 6: sequencing of the lesson steps' in Leon's lesson plan for post-intervention the following episode of plTSPCK was identified. The evidence of this episode was seen in the following extract.

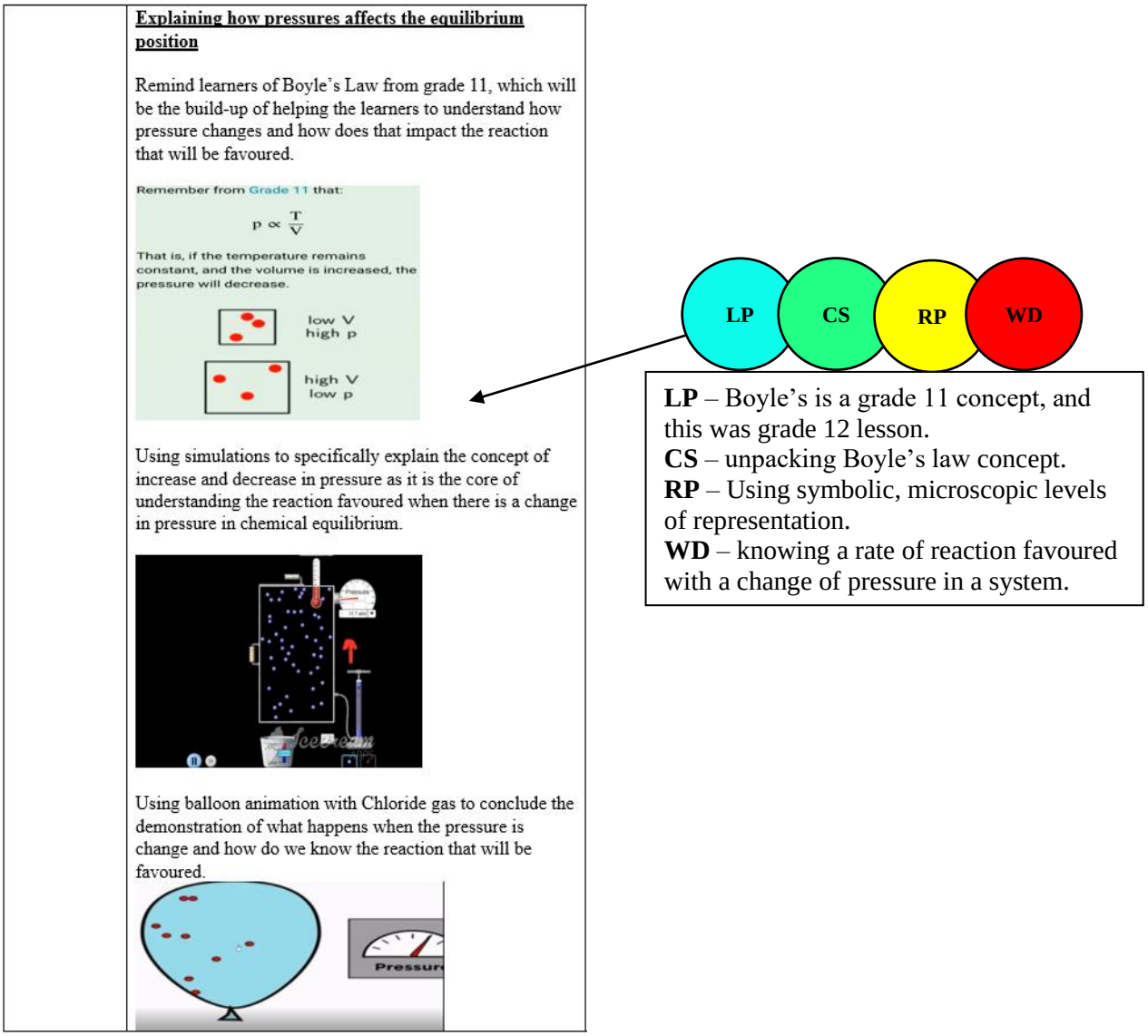


Figure 4.5: Leon's plTSPCK episode (post-intervention)

In the above extract there is presence of LP, CS, RP and WD components of TSPCK interacting together in a complimentary manner to transform explanations. The LP component is visible from the beginning of this episode when Leon recapped on previous concept of Boyle's law that learners did in grade 11 to explain how pressure affects the Equilibrium position. Leon

used the CS component in selecting specific content knowledge to recall from the concept of Boyle's law that specifically links with how the change of pressure affects gases at Equilibrium position.

The RP component is visible at symbolic level from the formulas, microscopic level from the gas particles and macroscopic level from the balloon simulation to understand what happens when the pressure is reduced inside the gas particles. According to Jusniar (2020), knowing which reaction will be favoured in a Chemical Equilibrium when there is a change of pressure, temperature or concentration is one of complex concepts that learners struggle to understand. Hence, it requires teachers to be careful in their explanations of this concept. Consequently, Leon used LP, CS, and RP component to lead his learners to understanding which reaction will be favoured when there is change of pressure in the system, making this a WD component of TSPCK. As a result, the following TSPCK maps can be drawn for this plTSPCK episode.

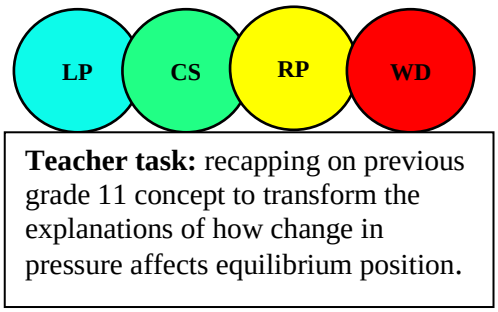


Figure 4.5.1: Leon's plTSPCK episode (post-intervention)

According to Mavhunga and Rollnick's (2013) rubric, the above episode shows '*Exemplary'* plTSPCK. This is so because the LP component was transformed using CS, and RP component to show WD component of TSPCK to bring about clear constructive explanations. Furthermore, there is a clear logic in the steps that will be used in unpacking this concept and clear connection between how different concepts are planned to link with each other.

iii) Leon's post intervention eTSPCK

Episode: Effect of pressure in Chemical Equilibrium position

In this episode Leon was explaining how change in pressure affects the Equilibrium position, where he started by displaying the following slide, in his video lesson:

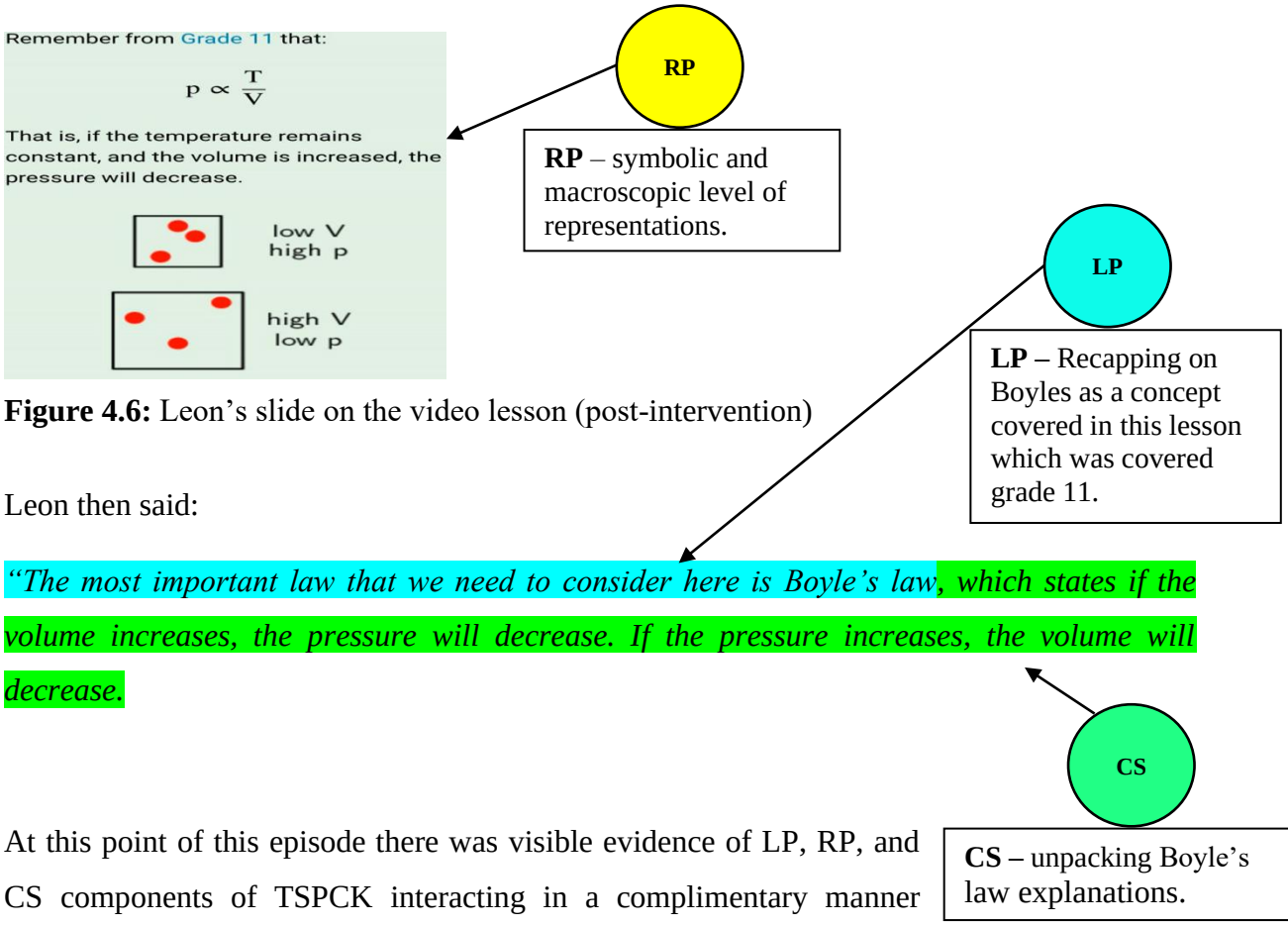


Figure 4.6: Leon's slide on the video lesson (post-intervention)

Leon then said:

"The most important law that we need to consider here is Boyle's law, which states if the volume increases, the pressure will decrease. If the pressure increases, the volume will decrease.

At this point of this episode there was visible evidence of LP, RP, and CS components of TSPCK interacting in a complimentary manner showing an interwoven TSPCK map which as follow.

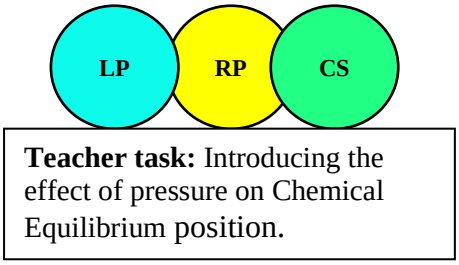


Figure 4.6.1: Leon's eTSPCK episode (post-intervention)

The above **Figure 4.6.1** TSPCK map shows LP, RP, and CS components of TSPCK interacting together in a clustering manner to transform explanations of how pressure can affect the Equilibrium position. According to Mavhunga and Miheso's (2021) rubric, the portion of this episode appears in '*proficient'* enactment of TSPCK to transform explanations.

Leon then showed the following simulation to specifically help learners conceptualize what happens in gas particles when pressure or volume increase or decrease, as he was still explaining how pressures changes according to Boyles law.

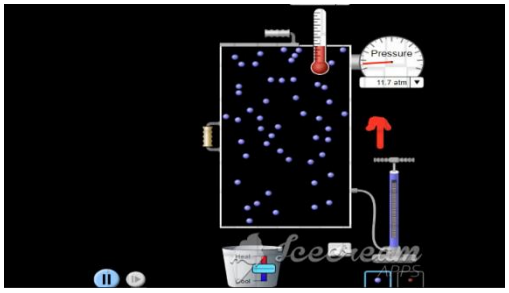
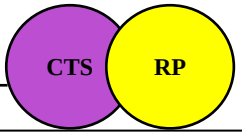


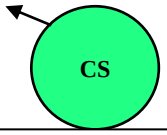
Figure 4.7: Leon's slide on the video lesson (post-intervention)



CTS – The simulation was intentional used to demonstrate the increase or decrease of pressure for learners to understand Le Chateliers principle effect in Chemical Equilibrium position.
RP – at a microscopic level

The simulation was then modified to reflect each of the conditions Leon was referring to as he made the following statement.

"…if we have more gas particles colliding and hitting the container, it means we have high pressure. If we have less gas particles in a container colliding and hitting a container, it means we have a lower pressure, let us involve Le Chatelier's principle in this discussion.



CS – intentional including Le Chatelier's principle to help the learners understand the effect of pressure.

In the above segment Leon was addressing how pressure changes in the system, what happens at a microscopic level and how that leads to Chemical Equilibrium position being affected. In the above segment there is a visibility CTS, RP, and CS components of TSPCK. Consequently, the following TSPCK map can be drawn.

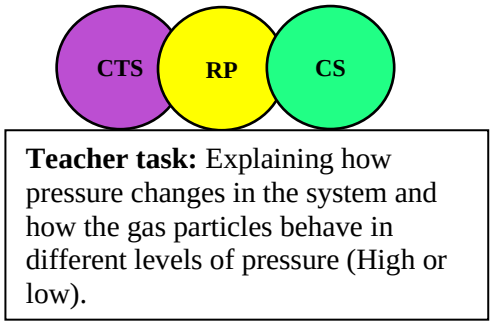


Figure 4.7.1: Leon's eTSPCK episode (post-intervention)

The above map shows an interwoven structure of TSPCK components where there is a visibility of CTS, RP and CS components of TSPCK interacting together in complimentary manner to enhance the explanations. As such, according to Mavhunga and Miheso's (2021) rubric the portion of this episode appears in '*proficient'* enactment of TSPCK to transform explanations.

In the video, Leon went to elaborate and said the following:

"Now, let's say you squeeze the balloon meaning you are increasing the pressure. "According to Le Chatelier's principle the system will try to undo this, or it will try to change this by decreasing the pressure. So, for pressure to decrease, fewer particles will be preferable, so that there will be less collision between particles and the walls of the container."

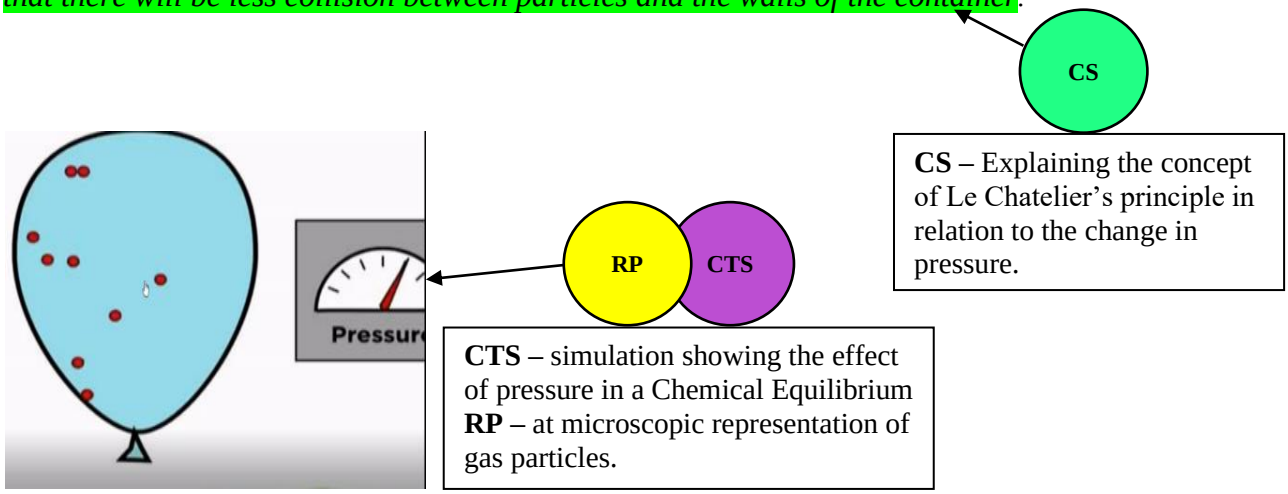


Figure 4.8: Leon's slide on the video lesson (post-intervention)

In the above segment of this episode, Leon used the balloon to demonstrate Le Chateliers principle. He was explaining how the change in pressure affect the particles in the gas and how Le Chatelier's principle corrects the system to re-obtain the Equilibrium position. Thus, in this

segment of Leon's further explanation of this concept there is visible CTS, RP, and CS components of TSPCK. The following TSPCK map can be drawn from this segment.

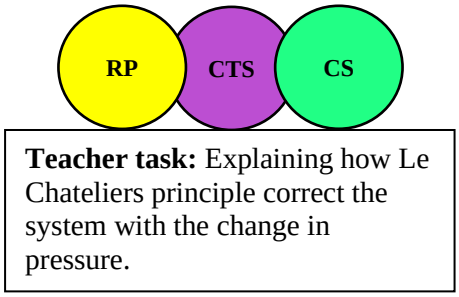


Figure 4.8.1: Leon's eTSPCK episode post-intervention

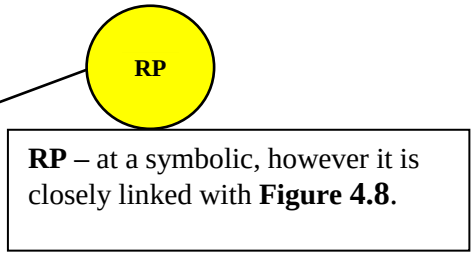
The above TSPCK map, shows CTS, RP, and CS components of TSPCK interacting together in a complimentary manner. Thus, segment this episode shows '*proficient'* enactment of eTSPCK used to transform explanations in accordance with Mavhunga and Miheso's (2021) eTSPCK rubric.

Leon went on to say:

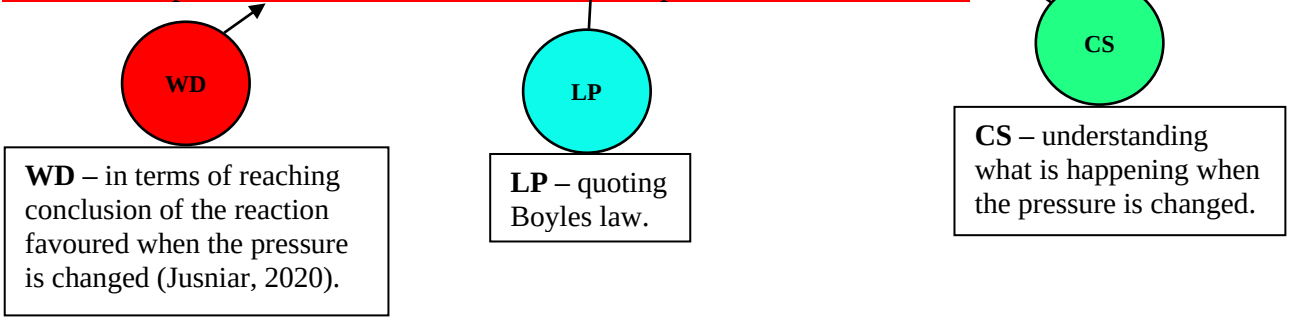
"So, looking at the balance equation for chloride gas, and mono atomic chloride the reaction is reversible.



Figure 4.9: Leon's slide in the lesson video



If we decide to increase the volume, meaning we are decreasing pressure as Boyle's law states. There will be a decrease in collision between particles and walls of the container. According to Lee Chateliers principle, the equilibrium will try to increase the pressure by favouring the reaction that produces more molecules. So that the pressure can increase".



In the above segment of this episode, there is visibility of RP, LP, CS and WD components of TSPCK interacting together in a complimentary manner. This episode interacts in an interwoven manner, which shows the following structure of TSPCK maps.

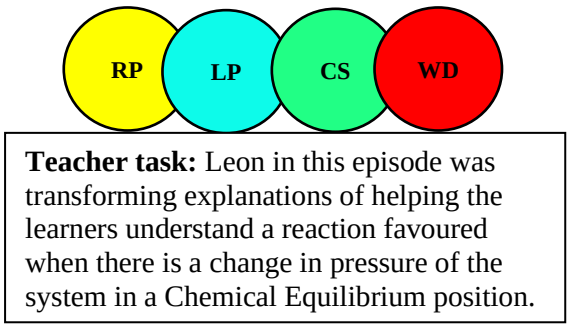


Figure 4.9.1: Leon's eTSPCK episode (post-intervention)

The above TSPCK map, shows RP, LP, CS, and WD components of TSPCK interacting together in a complimentary manner. Thus, this segment shows '*Sophisticated'* episode of eTSPCK used to transform explanations in accordance with Mavhunga and Miheso's (2021) eTSPCK rubric

Thus, in this episode the final TSPCK map is as follows:

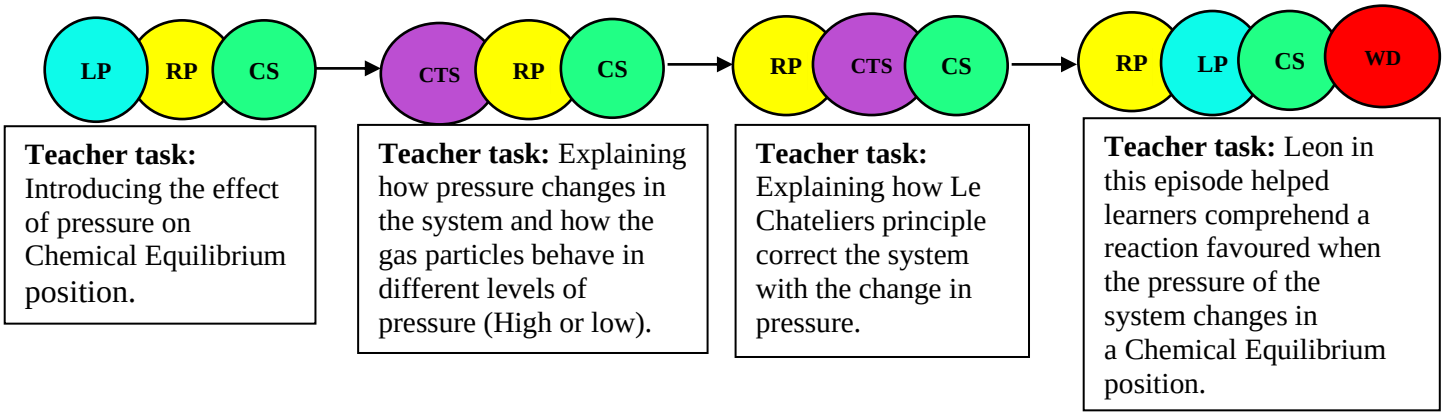


Figure 5: Summary Leon's eTSPCK episode (post-intervention)

This above **Figure 5** for TSPCK map appear in that way because Leon started by first introducing the concepts of pressure according to Boyle's law which was done in the previous grade. He further highlighted the importance of Boyle's law towards the understanding of this lesson's content knowledge. He then used microscopic and symbolic level of representation

towards recapping on Boyle's law concept. At this point there was visible complimentary interaction of interwoven structure between LP, RP, and CS as seen on **Figure 4.6.1**. This explains the first interaction of this components in the above map.

Furthermore, this was linked with a Physics Education Technology (PhET) simulation that he used specifically to demonstrate the concept of increase and decrease in pressure showing CTS component of TSPCK. The simulation was aimed at unpacking the behaviour of gas particles at a microscopic level of representation when pressure changes. This demonstrated the second episode first seen in Figure 4.7.1, which showed the CTS, RP, and CS components of TSPCK interacting in a complementary manner. While demonstrating this concept Leon introduced the concept of Le Chateliers principle and used a simulation of a balloon filled with Chloride gas to explain the reaction that is favoured when there is change of pressure in Equilibrium position of gases. This further showed RP, CTS, and CS components of TSPCK interacting together in a complimentary manner as first evidenced in **Figure 4.8.1** TSPCK map.

Thus, these segments of this episode further resulted in the last interwoven structure of TSPCK complimentary and clustering component interaction seen in **Figure 5**. The overall manner of interaction in this episode shows an interwoven and linear interaction between TSPCK components. In concluding, first episode **Figure 4.6.1**, was enactment at '*Proficient'* according to Mavhunga and Miheso's (2021) rubric. Furthermore, second episode **Figure 4.7.1** showed '*Proficient'* eTSPCK. The third segment (**Figure 4.8.1)** further showed *'Proficient'* enactment of TSPCK in accordance with Mavhunga and Miheso (2021) rubric for eTSPCK.

The last segment in **Figure 5** showed '*sophisticated'* of eTSPCK as the highest enactment of TSPCK according to Mavhunga and Miheso (2021) eTSPCK rubric. Thus, in this episode explanations were transformed using the highest enactment of TSPCK which showed clustering of different TSPCK components. Which agrees with Mavhunga and van der Merwe (2020) findings of component interactions in highest enactment TSPCK episodes.

4.5 TABLE SUMMARY OF FINDINGS (LEON)

Table 4.4: Leon's lesson analysis overview

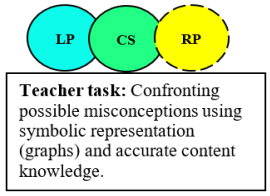
<table>
<tr><th colspan="4">PRE-INTERVENTION TSPCK EPISODES</th></tr>
<tr><td>Pre-intervention plTSPCK (lesson plans)</td><td>Observations</td><td>Pre-intervention eTSPCK (video)</td><td>Observations</td></tr>
<tr><td>

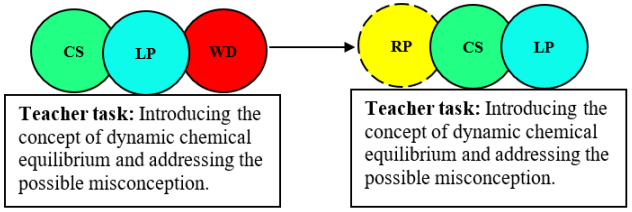
Figure 4.2.1: Leon's plTSPCK episode (Pre-intervention)
Comment: plTSPCK evidenced 'developing' (Mavhunga & Rollnick, 2013)</td><td>The lesson plan was well written with good content knowledge that Leon prepared for teaching.</td><td>

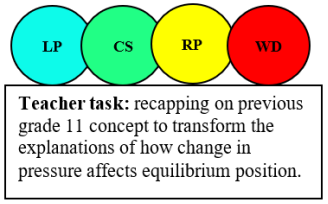
Figure 4.4: Summary of Leon's eTSPCK episode (Pre-intervention)
Comment: eTSPCK evidenced 'proficient' (Mavhunga & Miheso, 2021)</td><td>The video was functional and 15 minutes long. There were some minor mismatch issues between audio and the slides of the video.</td></tr>
<tr><th colspan="4">POST-INTERVENTION TSPCK EPISODES</th></tr>
<tr><td>Post-intervention plTSPCK (lesson plans)</td><td>Observations</td><td>Post-intervention eTSPCK (video)</td><td>Observations</td></tr>
<tr><td>

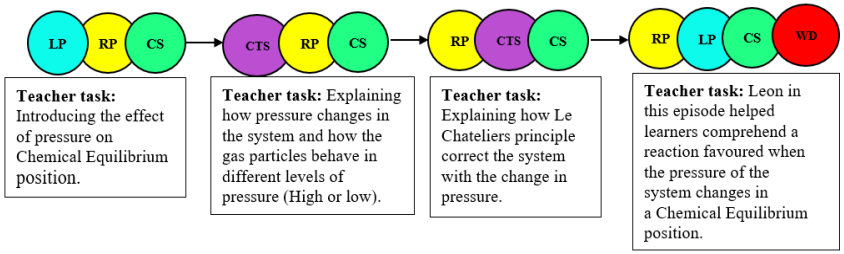
Figure 4.5.1: Leon's plTSPCK episode (post-intervention)
Comment: plTSPCK evidenced 'Exemplary' (Mavhunga & Rollnick, 2013)</td><td>The lesson plan was well constructed with visible intention of how things are intended to be done in the pre-recorded video.</td><td>

Figure 5: Summary Leon's eTSPCK episode (post-intervention)
Comment: eTSPCK evidenced 'Sophisticated' (Mavhunga & Miheso, 2021)</td><td>The video showed improved functionality. It was kept at 15 minutes long. There was improved used of representations.</td></tr>
</table>

The same procedure was followed for Lebo and Mandy's lesson plans and digital pre-recorded video lessons. See the following TSPCK maps that were concluded.

4.6 Lebo's TSPCK (pre-intervention)

TSPCK pre-intervention lesson plan episode

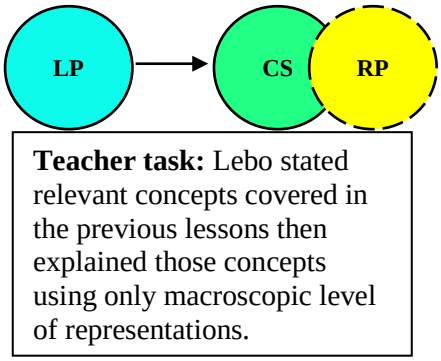


Figure 6: Lebo's plTSPCK episode (pre-intervention)

TSPCK pre-intervention video lesson episode

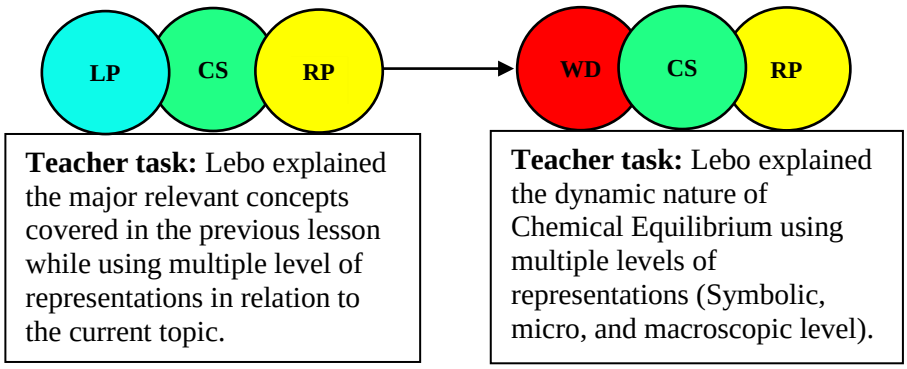


Figure 6.1: Lebo's eTSPCK (pre-intervention)

4.7 Mandy's TSPCK (pre-intervention)

TSPCK pre-intervention lesson plan episode

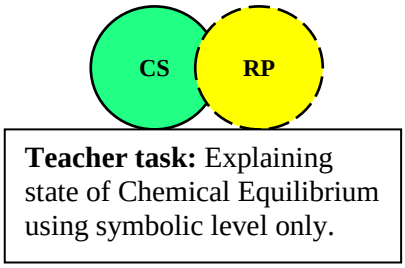


Figure 7: Mandy's plTSPCK episode (pre-intervention)

TSPCK pre-intervention video lesson

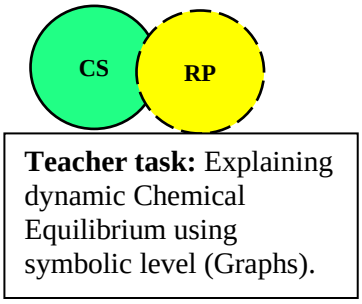


Figure 7.1: Mandy's eTSPCK episode (pre-intervention)

4.6.1 Lebo's TSPCK (post-intervention)

TSPCK post-intervention lesson plan episode

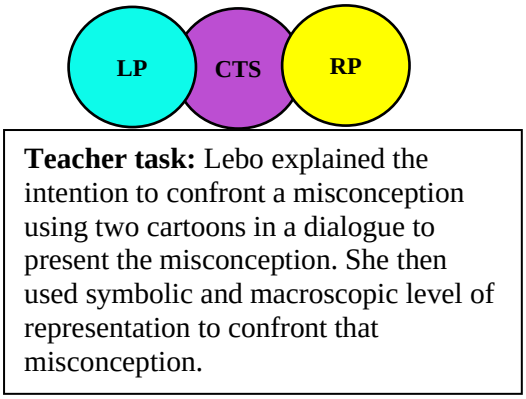


Figure 8: Lebo's plTSPCK episode (post-intervention)

TSPCK post-intervention video lesson episode

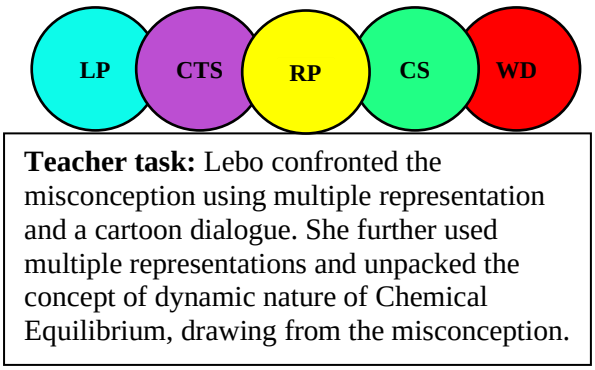


Figure 8.1: Lebo's eTSPCK episode (post-intervention)

4.7.1 Mandy's TSPCK (post-intervention)

TSPCK post-intervention lesson plan episode

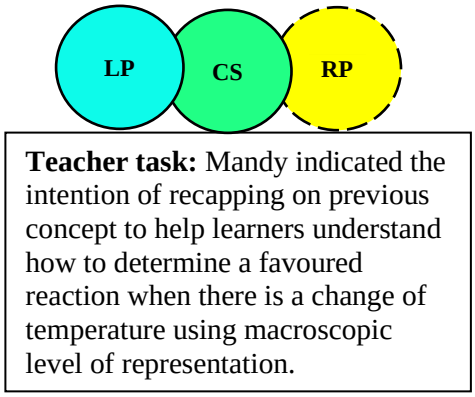


Figure 9: Mandy's plTSPCK episode (post-intervention)

TSPCK post-intervention video lesson episode

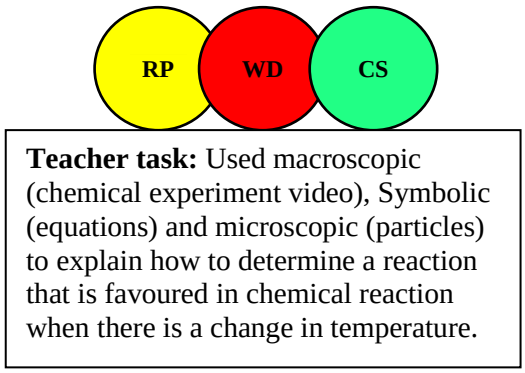


Figure 9.1: Mandy's eTSPCK episode (post-intervention)

4.8 TABLE SUMMARY OF FINDINGS (LEBO)

Table 4.5: Lebo's lesson analysis overview

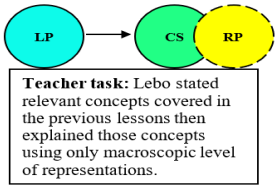
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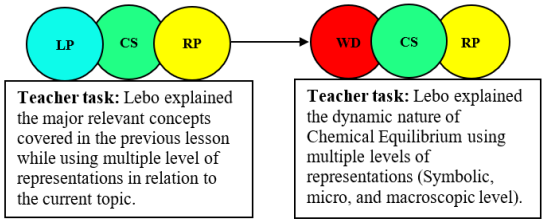
Figure 6: Lebo's plTSPCK episode (pre-intervention)
Comment: plTSPCK evidenced 'basic' (Mavhunga & Rollnick, 2013)</td><td>There were visible intentions of how the lesson is planned to be recorded in the video with good content knowledge.</td><td>

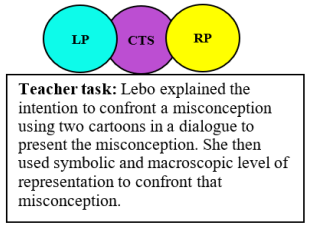
Figure 6.1: Lebo's eTSPCK (pre-intervention)
Comment: eTSPCK evidenced 'proficient' (Mavhunga & Miheso, 2021)</td><td>The video was kept at 15 minutes long. They were good use of different forms of representations.</td></tr>
<tr><th colspan="4">POST-INTERVENTION TSPCK EPISODES</th></tr>
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<tr><td>

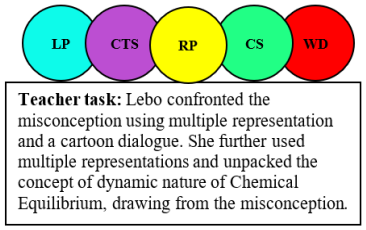
Figure 8: Lebo's plTSPCK episode (post-intervention)
Comment: plTSPCK evidenced 'developing' (Mavhunga & Rollnick, 2013)</td><td>The planning was very close with the pre-recorded video. There was consideration of activities that can be conducted within the video platform.</td><td>

Figure 8.1: Lebo's eTSPCK episode (post-intervention)
Comment: eTSPCK evidenced 'Sophisticated' (Mavhunga & Miheso, 2021)</td><td>The video had the teacher's video explaining the content displayed on the slides. It was functional and kept at 10 minutes long.</td></tr>
</table>

4.9 TABLE SUMMARY OF FINDINGS (MANDY)

Table 4.6: Mandy's lesson analysis overview

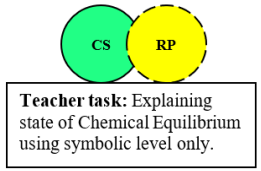
<table>
<tr><th colspan="4">PRE-INTERVENTION TSPCK EPISODES</th></tr>
<tr><td>Pre-intervention plTSPCK (lesson plans)</td><td>Observations</td><td>Pre-intervention eTSPCK (video)</td><td>Observations</td></tr>
<tr><td>

Figure 7: Mandy's plTSPCK episode (pre-intervention)

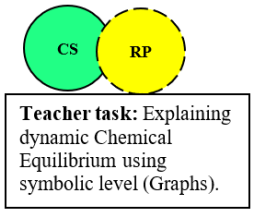
Comment: plTSPCK evidenced 'basic' (Mavhunga & Rollnick, 2013)</td><td>The lesson plan was well constructed however, there are some aspects that were only suitable for physical classroom like learner discussions.</td><td>

Figure 7.1: Mandy's eTSPCK episode (pre-intervention)

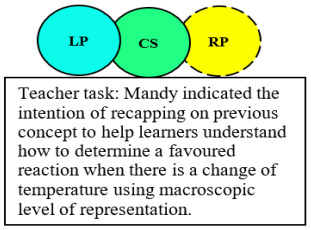
Comment: eTSPCK evidenced 'simple' (Mavhunga & Miheso, 2021)</td><td>The video was kept at about 15 minutes. The video was functional with lack of representations. Mandy made the video to be more of an audible platform than visual.</td></tr>
<tr><th colspan="4">POST-INTERVENTION TSPCK EPISODES</th></tr>
<tr><td>Post-intervention plTSPCK (lesson plans)</td><td>Observations</td><td>Post-intervention eTSPCK (video)</td><td>Observations</td></tr>
<tr><td>

Figure 9: Mandy's plTSPCK episode (post-intervention)

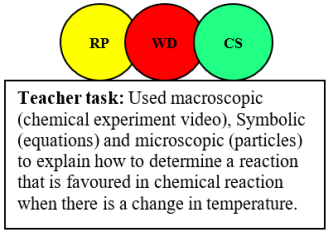
Comment: plTSPCK evidenced 'developing' (Mavhunga & Rollnick, 2013)</td><td>Sequencing of core concepts improved logically. Video platform activities were better planned.</td><td>

Figure 9.1: Mandy's eTSPCK episode (post-intervention)

Comment: eTSPCK evidenced 'proficient' (Mavhunga & Miheso, 2021)</td><td>The lesson lasted over 20 minutes, with most time spent on the pre-recorded experiment embedded within the lesson.</td></tr>
</table>

Looking at the above **Table 4.4 – Table 4.6** there are clear patterns of change and development between lesson plans designed before and after the TSPCK intervention program. This is also the case with the digital teaching video lesson where there are patterns of improvement in post TSPCK intervention lessons. There were commonalities across all the plTSPCK where there is limited visibility of TSPCK characterised by one episode in all the TSPCK in planning identified episodes. Hence, the nature of plTSPCK as reflected in literature (Malcolm et al., 2019; Mavhunga & van der Merwe, 2020). TSPCK in enactment has a different nature from plTSPCK where the TSPCK in enactment has more than one episode and have clusters of TSPCK components. Furthermore, TSPCK in planning undergoes structural change when it is enacted, however the intention of the lesson remains the same. This results will further be discussed in greater details in the next discussions chapter, Chapter 5.

The participating PSTs were also asked to reflect on their experience of teaching in the pre-recorded video as compared to their experience of teaching in a physical classroom. They were asked about their experience in using the videos that they created in their classrooms during their teaching practicum. Thus, the following was captured from their reflections.

4.10 Reflections of teaching in a pre-recorded video

The first observation in the reflections that PSTs highlighted is the restrictions that the video environment comes with in comparison to the actual traditional classroom space. For example, Mandy articulated that she wanted to address a misconception with first asking her learners questions to examine the presence of a misconception. However, the possibility of asking questions and getting responses in real time on videos is not possible. Hence, TSPCK enacted in a pre-recorded teaching videos is limited in terms of how they explore specific components in the digital recorded video. Thus, in this particular Mandy's reflection the appearance of LP component of TSPCK is limited in how it can be conducted within a digital space due to lack of human physical interaction. Which in turn limits the TSPCK components visibility in a particular episode.

However, Lebo showed that this challenge can be overcome through creative means of exploring digital platform. In demonstrating this in her video she used a cartoon representation appearing in a form of conversation that introduces the presented specific misconception. Thus, instead of asking questions to the learners she used an approach of introducing a misconception in a manner suitable for a video space.

Furthermore, PSTs indicated that the creation of the pre-recorded video often takes time. In addition, they stated that digital videos are a useful tool for self-reflection since when they watch them after creation, they can detect some mistakes they did. This is consistent with findings by Zhang et al (2017) which suggested that teaching in a pre-recorded videos is a good reflection tool of one's teacher practices. They also indicated that the pre-recorded videos that they did were long when trying to implement them in class learners loses concentration easily. This is in line with studies such as Mavhunga et al (in press) which states that teaching in a digital video require specific consideration of factors that affect learning within a digital platform.

On the other hand, Mandy indicated enjoyment in designing these pre-recorded videos and stated that there seems to be to some extent better than an actual classroom as they are no issue of having to discipline learners. In contrast, Leon stated that videos lack human communication and limits other significant aspect of teaching like being able to recognize learner confusion as you are teaching. The literature review of this study agrees with these reflections of the participating PSTs as it is articulated on the limitations of the video section **2.11**. Hence, this limitations affects the quality of teaching in recorded videos.

This Chapter will now be followed by the discussion Chapter where all the results of this study will be discussed in greater details.

CHAPTER 5: DISCUSSIONS OF THE FINDINGS

Abstract

The main purpose of this study was to examine the nature of TSPCK displayed in the Chemistry PSTs self-developed teaching videos on the topic of Chemical Equilibrium. This chapter provides detailed discussions of the findings that were analysed in the previous chapter, Chapter 4. It further, answers this study's research questions. This chapter concludes with the reflections of the used theoretical framework and future recommendations.

5.1 Background Summary

The introduction to this study presented the purpose of this study as focused on examining the nature and quality of TSPCK, how it behaves or changes when it is observed from self-recorded teaching videos specifically on the topic of Chemical Equilibrium. In discussing the findings of this study, it is important to first recall the main research question, which is as follows.

The main research question: What is the nature and quality of PSTs' TSPCK displayed in teacher, self-recorded teaching videos on the topic of Chemical Equilibrium?

As seen in Chapter 1 of this study, the following sub-questions were developed to serve as guiding questions for the aforementioned research main question. Consequently, the research sub-questions will be addressed first in this chapter, as they will serve as a foundation for answering this study's research main question. The research sub-questions for this study are re-presented here for ease of reference.

Research sub-questions

1. What is the nature and quality of PSTs' TSPCK in the planning for teaching Chemical Equilibrium through a teacher self-recorded teaching video?
2. What is the nature and quality of PSTs' enacted TSPCK (eTSPCK) in self-recorded teaching videos on Chemical Equilibrium?
3. What is the relationship between the nature and quality of planned TSPCK (plTSPCK) and enacted TSPCK (eTSPCK) in teacher self-recorded teaching videos on Chemical Equilibrium?

The above-mentioned sub-questions of this study will be answered according to the same order as they are mentioned above.

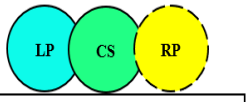
5.2 The responses to research questions

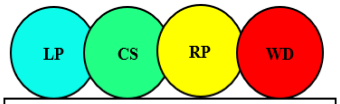
5.2.1 The response to sub-research question 1

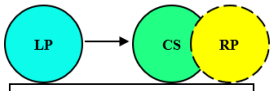
Sub-research question 1: What is the nature and quality of PSTs' TSPCK in the planning for teaching Chemical Equilibrium through a teacher self-recorded teaching video?

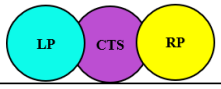
Looking at the identified TSPCK episodes in the planning tasks of the three PSTs a specific pattern is observed. For ease of reference, the TSPCK episodes presented in Chapter 4, **Tables 4.4 – 4.6** are herein presented again in **Table 5** to highlight the patterns of TSPCK in planning.

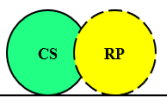
Table 5: Summary of all plTSPCK episodes as identified in **Tables 4.4 – 4.6**

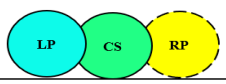
<table>
<tr><th colspan="3">TSPCK EPISODES IN PLANNING</th></tr>
<tr><th>PST's</th><th>Pre-intervention plTSPCK</th><th>Post-intervention plTSPCK</th></tr>
<tr><td>Leon</td><td>

Teacher task: Confronting possible misconceptions using symbolic representation (graphs) and accurate content knowledge.
Figure 4.2.1: Leon's plTSPCK episode (Pre-intervention)</td><td>

Teacher task: recapping on previous grade 11 concept to transform the explanations of how change in pressure affects equilibrium position.
Figure 4.5.1: Leon's plTSPCK episode (post-intervention)</td></tr>
<tr><td>Lebo</td><td>

Teacher task: Lebo stated relevant concepts covered in the previous lessons then explained those concepts using only macroscopic level of representations.
Figure 6: Lebo's plTSPCK episode (pre-intervention)</td><td>

Teacher task: Lebo explained the intention to confront a misconception using two cartoons in a dialogue to present the misconception. She then used symbolic and macroscopic level of representation to confront that misconception.
Figure 8: Lebo's plTSPCK episode (post-intervention)</td></tr>
<tr><td>Mandy</td><td>

Teacher task: Explaining state of Chemical Equilibrium using symbolic level only.
Figure 7: Mandy's plTSPCK episode (pre-intervention)</td><td>

Teacher task: Mandy indicated the intention of recapping on previous concept to help learners understand how to determine a favoured reaction when there is a change of temperature using macroscopic level of representation.
Figure 9: Mandy's plTSPCK episode (post-intervention)</td></tr>
</table>

The first observation in the above Table is the fact that the pre-intervention lessons plan of Leon, Lebo and Mandy had plTSPCK (TSPCK observed in planning) episodes. This shows that the participants started the intervention with some level of TSPCK, Leon at '*Developing'* level, Lebo and Mandy at '*Basic'* level. It is to be inferred that the participants also had a reasonable level of understanding of the content knowledge of the topic, Chemical Equilibrium. This is drawn from the literature that TSPCK cannot be portrayed without the understanding of content knowledge (de Sá Ibraim & Justi, 2021).

It is also observed that the quality of plTSPCK in their planning for a self-recorded teaching video improved by 1 level, depicted by the presence of three different components of TSPCK interacting, as per the rubric used (Mavhunga & Rollnick, 2013). This was after being exposed to the intervention, signalling to the positive influence of the intervention. However, this is expected as the same intervention, referred to as the signature intervention in many other TSPCK studies, has been reported to have the same effect (e.g., Akinyemi & Mavhunga, 2021; Malcolm et al., 2019).

However, of interest to this study is that, for all the participants, it is noted that only a single TSPCK episode could be identified from their planning. This is reflective of the limitation of reducing what teachers know and plan to do to a written format, often they unable to write fully as it is also tedious and difficult to express. The similar observations were reported in the study of Mavhunga and van der Merwe (2020), where the TSPCK episodes visible in the planning tasks and actual enactment of the same lessons plans in traditional classrooms were studied. Thus, with respect to the purpose of this study, the results confirm the same limitations reported in traditional classrooms settings to be the case even when the planning is for a self-video recorded lesson format.

Another observation of note is the idiosyncratic nature (Park & Chen, 2012) of the observed TSPCK episodes even those of the same quality (e.g., Leon and Lebo's pre-PlTSPCK episodes had the same number of different component seen interacting). This is further indicative of Carlson et al.'s (2019) articulation that PCK is personal, and individual teachers draw on the TSPCK components in different ways, even when explaining the same thing.

In view of the above listed patterns, the response to the first research question is:

The nature of TSPCK in teacher lesson plans for self-recorded video lessons appears to remain constraint and limited in visibility. Lessons plans as teacher tasks seem to offer very few, specifically only single, opportunities for portraying the teachers' TSPCK even when the planning is for digital recording. The quality of their plTSPCK including the extent of its improvement post the intervention, differed from person to person as seen in previous studies (e.g., Mavhunga & van der Merwe, 2020).

5.2.2 The response to sub-research question 2

Sub-research question 2: What is the nature and quality of PSTs' enacted TSPCK (eTSPCK) in self-recorded teaching videos on Chemical Equilibrium?

Similarly, to formulating the response to the sub-research question 2, the TSPCK episodes identified in the self-recorded teaching videos of the participants reported in Chapter 4, **Tables 4.4 – 4.6** are summarized herein for ease of reference, see **Table 5.1**. As indicated before, TSPCK episodes observed in the realm of teaching enactment are referred to as (eTSPCK). See this table in the following page.

Table 5.1: Summary of all eTSPCK episodes as identified in Chapter 4, **Tables 4.4 – 4.6**

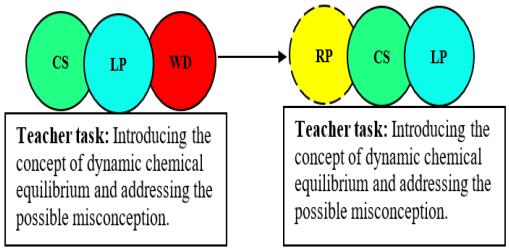
<table>
<tr><th colspan="3">TSPCK EPISODES IN ENACTMENT</th></tr>
<tr><th>PST's</th><th>Pre-intervention eTSPCK</th><th>Post-intervention eTSPCK</th></tr>
<tr><td>Leon</td><td>

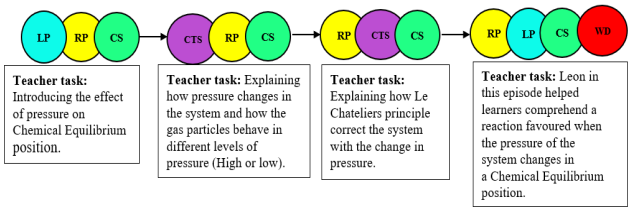
Figure 4.4: Summary of Leon's eTSPCK episode (Pre-intervention)</td><td>

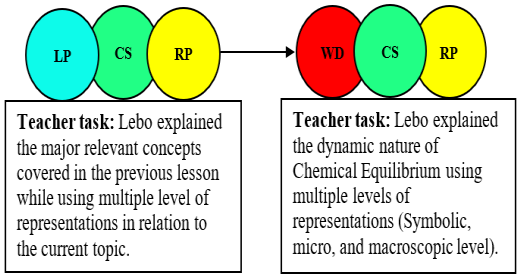
Figure 5: Summary Leon's eTSPCK episode (post-intervention)</td></tr>
<tr><td>Lebo</td><td>

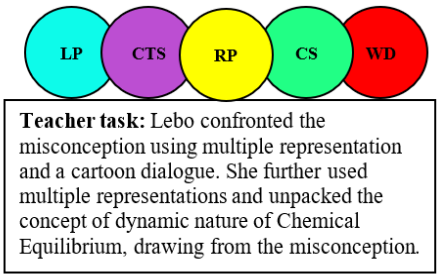
Figure 6.1: Lebo's eTSPCK (pre-intervention)</td><td>

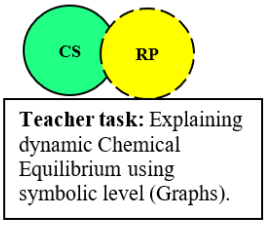
Figure 8.1: Lebo's eTSPCK episode (post-intervention)</td></tr>
<tr><td>Mandy</td><td>

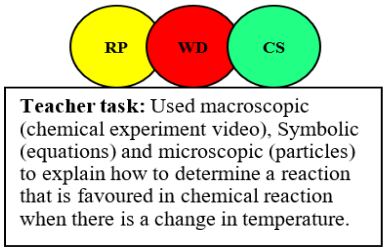
Figure 7.1: Mandy's eTSPCK episode (pre-intervention)</td><td>

Figure 9.1: Mandy's eTSPCK episode (post-intervention)</td></tr>
</table>

The nature of the patterns in, **Table 5.1**, speaks to the heart of the purpose of this study. Having seen the nature of the patterns visible in the planning TSPCK it is noticeable how the nature of the single plTSPCK have changed when observed in the realm of enactment. The eTSPCK appear to emerge in enactment as a cluster of related episodes. What makes them a cluster is in their analysis in Chapter 4, for each case, it was clearly visible how a teacher completed a particular explanation and moved to the next while keeping connection to the previous one. This pattern is observed in both the pre and the post-intervention episodes of clusters of Leon and Lebo in the exception of Mandy who remained with a single episode in each case. The

clustering effect is window reflecting the complexity of classroom enactment, that enables the display of teacher's actions as he reflects in action (Alonzo, et al, 2019). This behaviour in the nature of TSPCK episodes is similar to that reported in other studies (Akinyemi & Mavhunga, 2021; Mavhunga & van der Merwe, 2020) with traditional classroom teaching settings.

The patterns in **Table 5.1** above further indicate an improvement in the quality of the eTSPCK episodes across the pre-post in Leon' case from '*proficient'* to '*exemplary'* according to the rubric by Mavhunga and Miheso (2021). Mandy also registered an improvement in the quality of the pre-post episodes from '*simple'* to '*proficient*'. In relation to the purpose of the study, the patterns of the eTSPCK displayed, both in pre- and post-intervention, showed no difference to those reported in many other studies with traditional TSPCK. For example, Park and Chen (2012) indicated that the components of PCK that were visible in the teaching of Life science teachers were about learner understanding, representations and instructional strategies. In a similar vein, Aydin and colleagues (2014) reported that the only components of PCK that were visible in the enactment of science teachers teaching electrochemical cells and nuclear reactions were those that were content specific, similar to those of TSPCK.

In view of the above listed patterns, the response to the second research question is:

The nature of TSPCK observed manifesting in the teaching enactment in the teacher self-video recorded lessons, showed no evidence of difference to that reported in previous studies about the manifestations of TSPCK in classroom settings. What is widely reported about the nature TSPCK episodes in enactment settings as alluded above, is the clustering behaviour and visibility of content specific knowledge components rather than discipline specific components of PCK. In these patterns, no evidence of new considerations about either the digital functions of recording or the recipients of the recorded lesson were made. This indicates that the video recording of lessons has the powerful potential to portray the same kind of TSPCK manifestation as in actual classrooms.

5.2.3 The response to sub-research question 3

Sub-research question 3: What is the relationship between the nature and quality of planned TSPCK (plTSPCK) and enacted TSPCK (eTSPCK) in teacher self-recorded teaching videos on Chemical Equilibrium?

Likewise, in response to the above sub-question three response, **Table 5** and **Table 5.1** above offer a summary of all the analysis and findings conducted in this study for both plTSPCK and eTSPCK for pre and post the TSPCK intervention. The first visible relationship between, the PSTs plTSPCK and eTSPCK is the fact that the higher the quality in planning the higher the quality in enactment. For example, with reference to Mandy's pre-intervention plTSPCK, the episode identified in her planning is *'basic'* quality plTSPCK according to Mavhunga and Rollnick's (2013) rubric. The enactment of this TSPCK episode reflected to be *'simple'* eTSPCK according to Mavhunga and Miheso (2021) rubric.

Furthermore, the components of TSPCK that were in planning were CS and RP, even in the eTSPCK they reflected to interact the same way reflecting poor TSPCK quality. On the contrary, when looking at Leon's plTSPCK in his respective lesson plan, both pre and post intervention cases, he had higher quality than the 'basic' level attained by Mandy and have resulted in teaching enactment of correspondingly higher quality. Thus, these patterns show that the quality of TSPCK in the planning directly influences the quality of TSPCK observed in enactment. This finding is not particularly reported in the studies cited above that were tracking the behaviour of traditional TSPCK from planning to enactment in traditional settings. Thus, it could be regarded as particularly more nuanced in this study.

The second observation is that the intentions reflected in the lesson's plans were retained in the enactment in a self-recorded video teaching enactment. This was true across all levels of quality of enactment as seen in both the pre and post cases (**Table 5.1**). However, the move from higher quality plTSPCK to teaching enactment, as seen in Leon's case, brings an additional display of complex structural changes in the use of the types of TSPCK components and their sequence. Leon's lesson plan reflected an episode of post-intervention plTSPCK generated by the interactions between LP, CS, RP and WD (**Table 5**). However, when it was in enactment, as shown in post-eTSPCK, **Table 5.1** it had blossomed into a cluster of eTSPCK episodes with different permutations of the same TSPCK knowledge components.

In view of the above listed patterns, the response to the third research question is:

The quality of plTSPCK reflected in the planning of teacher self-video recorded lessons appears to directly influence the quality eTSPCK manifesting in the enactment teaching of the planning. Furthermore, higher quality plTSPCK seem to facilitate the visible manifestation of the complex structural change in the interactions of the knowledge components of TSPCK. Like, with traditional classroom teaching cases. The intention of the lessons as captured in the lesson plans was adequately retained in the teacher self-video recorded lessons.

5.3 Features of importance extracted from the PSTs' reflections

The PSTs' reflections reported in Chapter 4, section **4.10** which were reflection to teach in pre-recorded digital videos pointed largely to what would differentiate the teacher self-video recorded lessons from actual brick and mortar traditional classroom settings. Participants pointed to the limitations of recorded teaching videos that they are restrictive and limits what the teacher wishes to do in creating an engaging environment. This view could be interpreted to point to the limited digital teaching capacity of PSTs, however more importantly as an important signal for the type of specific digital feature that future development programmes based on digital TSPCK should include in their teacher development programmes.

It is noted however that Lebo's teaching video made effort towards increasing engagement through a cartoon figure, it remains important that more specific high impact digital functions for learner engagement should be explored and taught explicitly. The next observable outcome from the PSTs reflection was on the affordances provided by recorded teaching video experience in that, other classroom social factors that maybe distractors such as ill-disciplined learners are not present. Furthermore, that the videos provide an immediate resource for self-reflection and evaluation leading to possible improvements.

5.4 The summative discussion

This study had a specific focus on understanding the nature and quality of TSPCK portrayed in teacher self-recorded videos. The rationale for this focus, was to begin the journey of discerning the refinement to be made to TSPCK when teaching is happening largely through digital platforms. The teacher self-video recorded lessons, as alluded to earlier, are regarded

in this study as intermediate between traditional classroom settings and fully immersed digital teaching settings. While there is a separate study, that has defined a refined version of TSPCK for teaching on digital platforms (Mavhunga, et al, in press), it was also important to determine the nature of TSPCK manifesting in the self-recorded videos whether it leans closer to this new construct or retains the well-studied traditional profile. The findings in this study reveal a very close similarity between the nature of eTSPCK in traditional classroom settings (brick and mortar environment) and in teacher self-recorded teaching videos. This finding has important implications to note:

- Firstly, they point to the additional value to be derived by teacher education programmes from teacher self-video recorded teaching lessons as a tool closely comparable to traditional classroom settings. Such videos are suggested by these findings to be promising to eliminate many of the social classroom factors that may pose distractors for PSTs in their early stages of learning to teach complex science topics based on TSPCK. This is not interpreted as a suggestion for eliminating real time teaching practice for all the benefits it offers. However, having PSTs who arrive in such practices with confidence and acquired high quality TSPCK acquired in pre-teaching experience through self-recorded videos, it may be of benefit to very teaching practice.
- Secondly, they point to the nature of TSPCK in the teacher self-video recorded lessons to be different to the refined construct of TSPCK, as digital-TSPCK. I have briefly shared in the literature review new features considered important for TSPK to respond fully. These included evidence of digital teacher competence beyond used of technology for recording and as representations in the lesson. They also included some consideration of the pedagogical multimedia principles responsive to the learner, who will receive the lesson in the digital format. The identified TSPCK episode had shown no reference to either of the new requirements.

To respond to this study's main question which is as follows.

Research main question: What is the nature and quality of PSTs' TSPCK displayed in teacher self-recorded teaching videos on the topic of Chemical Equilibrium?

In view of the responses to the sub-question that have been answered in this study, the response to the main question could be summarized as: The nature and quality of PSTs' TSPCK displayed in teacher self-recorded teaching videos on the topic of Chemical Equilibrium is similar to that observed manifesting in traditional classroom settings.

5.5 The Reflections on the theoretical framework used in this study

As much as promising findings were discovered in this study, however, using the theoretical construct of traditional TSPCK has limitations in terms of using it as a unit of analysis within a digital space. This is because there are no specific considerations of the video's platform as a mode of transporting eTSPCK. For example, Leon's video was of excellent quality in terms of TSPCK enactment. However, they are limitations brought by the fact of not having specific guidelines as he indicated learners losing concentration when watching the video as seen in his reflections. Thus, when taking eTSPCK to a video format as you in a classroom requires specific lens that are off, digital platform. This implies that making videos that are 15 minutes long may disadvantage students learning as the theory of cognitive load theory states (Mavhunga et al., in press).

The TSPCK framework alone is not enough in the space of digital realm this is the reason even this study had limitation of focusing the finding on the nature and appearance of TSPCK as it would in a traditional classroom as TSPCK alone is not equipped to deal with the analysis of lesson in digital space. Hence, there is a need of theoretical construct looking at factors that can guide the digital aspect of TSPCK enactment in a video format.

5.6 The Reflections on the limitations of the study

The design was nearly compromised by the poor performance of students producing reasonably good quality teaching videos. However, these videos were affected by the fact that they were too long. In other cases, they would know the content knowledge but struggled to represent it well in the video due to lack of training in digital skills required in teaching videos. Thus, the digital aspect seemed to be of significant factor in allowing this PSTs to be able to teach effectively in their pre-recorded video. On another hand, the results of this study should not be generalized as they are based on a small quantity of participants, however, they should be received as signals pointing to the probable nature of TSPCK in self-recorded videos**.**

5.7 Recommendations and conclusions of the study

From the findings of this study, it can be recommended that future studies exploring TSPCK enactment within a digital realm need to consider some aspects of digital environment such as the transitions to use in the videos, types of representation suitable for a digital space. Furthermore, there is a need for clearly defined guidelines of how an episode of TSPCK should look like within a digital video format. Thus, such frameworks can have a positive contribution in the notion of enacting TSPCK within a digital space. Furthermore, it is noted that within digital space content knowledge alone is not sufficient towards portraying the highest quality level of eTSPCK. Thus, for a teaching video to demonstrate high quality level of TSPCK there is a need for training within a digital space of video editing. Thus, there are reasons of defining new construct for defining TSPCK within a digital realm. This is in line with studies such as Mavhunga et al. (in press) which states that teaching in a digital video require specific consideration of factors that affect learning within a digital platform

In conclusion this study investigated three PSTs at wits school of education, where different levels of plTSPCK and eTSPCK were identified. The intended research main and sub-question were answered in greater details with recommendations implicated from this study. Hence, I conclude this study.

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PROJECT TITLE	Investigating the enacted TSPCK of pre-service teachers in teaching videos in the topic of chemical equilibrium.
INVESTIGATOR	**SIPHELELE NKOSINGIPHILE GCWENSA**
SCHOOL/DEPARTMENT OF INVESTIGATOR	WSoE
DATE CONSIDERED	15 November 2021
DECISION OF THE COMMITTEE	Approved unconditionally
RISK LEVEL	MINIMAL RISK
EXPIRY DATE	Date of submission of the Research Report

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DECLARATION OF INVESTIGATOR

To be completed in duplicate and **ONE COPY** returned to the Chairperson of the School/Department ethics committee.

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

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