DEVELOPING AND IMPLEMENTING CONCEPTUAL TEACHING STRATEGY IN ORGANIC CHEMISTRY THROUGH LESSON STUDY

A full dissertation submitted to the College of Humanities, School of Education at the University of Kwa-Zulu Natal

by

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Declaration

I declare that this research report is my work and it has not been copied from another source. I further declare that the words used are my own, except where sources were referenced. For any direct quotes found in this work from other works, original authors were acknowledged by citations and they appeared on the reference list. I solely make this declaration on my honour as a postgraduate student at the University of Kwa-Zulu Natal.

Sphesihle Winile Nsele

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Signature

Dedication

This work is dedicated to my parents and my family. If it were not for the presence of James Khumalo and Gertrude (MaSthole) Khumalo, I would not exist at all, my dad and mom. Unfortunately, you cannot see your child's effort because you are resting in His hands.

I devote this work to you, Sihle Nsele, my husband, for support. My kids, Syabusiswa, Syeneliseka, and Snengcebo, take this as one of the steps you need to land your feet on, for a better academic journey. May God Almighty give you wisdom that has no limitations. To both the Khumalo and Nsele families, may God protect you and keep you always. You are everything all human beings need.

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Abstract

In South Africa, Physical Sciences is one of the subjects with a high failure rate in the grade 12 National Senior Certificate (NSC) Examination. This observation was reported by the Department of Education and supported by several scholars.

This study reports a case study that focused on how practising teachers developed and implemented conceptual teaching strategies to improve the learning of organic chemistry. The study was underpinned by topic-specific pedagogical content knowledge (TSPCK), a theoretical construct emerging from Shulman's idea of content amalgamation with pedagogy.

There were three questions raised in this study: (i) What is the quality of teachers' pedagogical content knowledge in planning to teach a section of organic chemistry before the lesson study? (ii) What is a suitable conceptual teaching strategy for teaching grade a section of organic chemistry? (iii) How do teachers implement the conceptual teaching strategy developed through lesson study to teach a section of organic chemistry? Four in-service teachers participating in this study, including the researcher, were selected purposefully to participate in the study from Hlabisa Circuit in Mkhanyakude district in Kwa-Zulu Natal. Data was generated from the lesson plans of the participating teachers before lesson study intervention and further used two lesson study cycles to collect data through the use of the (content representation (CoRe).

The findings revealed that teachers had limited knowledge of the conceptual teaching strategy before lesson study intervention. After the exposure to the intervention, findings revealed that teachers successfully improved the quality of their conceptual teaching strategy through the use of CoRe as a planning template. Participants could show the good quality of TSPCK and how TSPCK components interacted during the lesson planning. Furthermore, this interaction of TSPCK components was also developed in enacted TSPCK.

Therefore, the lesson study played a critical role in improving planned TSPCK and enacted TSPCK. Further research is needed to explore the development of conceptual teaching strategies in other chemistry topics. Thus, the study recommended the inclusion of lesson study in the continuous professional development of teachers.

Keyword(s)

Conceptual Teaching Strategy, Content Representation Lesson Study, TSPCK, Organic Chemistry

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CHAPTER 1

1. BACKGROUND OF THE STUDY

In this opening chapter of this research dissertation, the foundation of the study is meticulously laid out through an exploration of its background. This section delves into the context and existing knowledge surrounding the research topic, providing readers with a comprehensive understanding of the subject's evolution over time. By immersing the audience in the background of the research, this chapter elucidates the broader context in which the study is situated, emphasising the gaps in current knowledge that necessitate further research. Through a review of existing literature, the chapter not only contextualises the research problem but also serves as a stepping stone for the subsequent chapters, providing the framework upon which the study is built. Through this comprehensive introduction, readers are guided into the heart of the research, gaining insight into the significance that underpins the entire thesis.

1.1 Introduction

In South Africa, Physical Sciences is one of the subjects with a high failure rate in the grade 12 National Senior Certificate (NSC) Examination. This observation is supported by several references such as Spaull (2015) and the annual diagnostic reports (Department of Basic Education, 2022). Among other factors contributing to this poor performance is the lack of an appropriate instructional context characterised by a meaningful consideration of the teacher, content, learner, and suitable instructional strategy as constituent elements of that context (Kolobe & Hobden, 2019). According to Kolobe and Hobden (2019, p. 3), "*strategies teachers use depend on their subject matter knowledge and their pedagogical content knowledge*" as key components of a good instructional context.

Recently, Mavhunga and Ndlovu (2023) advocated that content knowledge (CK) and Topic-specific pedagogical content knowledge (TSPCK) are vital knowledge domains necessary to facilitate the transformation of disciplinary science concepts into teachable forms of knowledge. This process of pedagogical transformation requires teachers to be able to use strategies that result in learners' understanding of each topic in the subject since pedagogical content knowledge (PCK) entails making content accessible to learners (Teffo, 2021). By definition, PCK points to a special kind of teacher knowledge that merges content and pedagogy in effective ways for teaching (Shulman, 1987). As a result, Kind and Chan (2019) foregrounded the importance of content knowledge in developing good and sound PCK. Considering what has been said about PCK and its taxonomies, TSPCK has been renowned as a suitable construct that assists teachers in planning and developing lessons using conceptual teaching strategies (Rollnick & Mavhunga, 2016). Thus, there is a need for teachers of Physical Sciences in South Africa to improve their conceptual teaching strategies and hence their TSPCK.

Within the South African curriculum framework, Physical Sciences is composed of physics and chemistry domains (Department of Education, 2011). Of these two domains, chemistry has the higher failure rate in the NSC examinations (Department of Basic Education, 2022). Various studies have argued that the difficulties encountered in teaching and learning chemistry are located in the navigation between the three levels of representation, namely the macroscopic, sub-microscopic, and symbolic levels (Green & Rollnick, 2006; Koopman, 2017; Meijer et al., 2009). The macroscopic level relates to the 'use of the five senses' to describe chemical phenomena while the sub-microscopic level focuses on particles and their interactions at a molecular level (Johnstone, 1991). The symbolic level entails the use of symbols (such as H_2O, S, and O_2) to represent chemical phenomena observed at the macroscopic and sub-microscopic levels (Meijer et al., 2009). It is generally accepted that the conceptual teaching and understanding of chemistry requires a strong integration of these three levels of representation when designing and implementing instructional strategies (Koopman, 2017).

1.2. Research problem

Regardless of the substantial research on PCK/TSPCK in teacher education, there is no adequate empirical evidence that shows a significant transference of teacher knowledge competencies from the perspectives of TSPCK to learners' performance in the sciences subjects (Ogegbo et al., 2019). While this observation is made, chemistry is regarded as one of the most difficult domains in the science discipline (Green & Rollnick, 2006). This is because of its abstract nature and the need to represent chemical phenomena from different levels of representation (Adu-Gyamfi & Asaki, 2022).

In chemistry, organic chemistry is considered one of the most challenging topics in school science (Crimmins & Midkiff, 2017; Danjou, 2020; Graulich et al., 2019). Organic chemistry constitutes a large section of the NSC Physical Sciences Paper 2 examination, which in turn contributes about 35% to the NSC Physical Sciences examination (Department of Basic Education, 2011). Organic reactions are one of the most poorly performed topics in the NSC Physical Sciences Paper 2 examination. According to the diagnostic report of the Department of Basic Education (2022), the organic reactions section of the examination showed a 10% decline in learner performance from 2020 to 2021. Though performance slightly increased in 2022, there are still a lot of misconceptions and errors reported on this topic. One of the challenges highlighted in the report is that "*learners did not see the link between reactants and products, and lacked basic knowledge in the topic"*. Besides, learners were, "*confusing the major product with the minor product during hydrohalogenation*", and "*lacked the necessary skills to analyse the question"* when given a flow diagram to represent different types of organic reactions (Department of Basic Education, 2022, p. 224). These reported misconceptions showed that learners have a weak conceptual understanding of the topic of organic chemistry.

Regarding the teaching of organic chemistry, Akinyemi and Mavhunga (2021) argued that specific instructional strategies that incorporate components of TSPCK need to be developed to provide pedagogical support to students thus potentially impacting their academic performance. However, the rectification of challenges identified is then left to the individual teacher's PCK as there is no platform for teachers to collaboratively develop conceptual teaching strategies to counteract common learners' misconceptions and errors. The lack of conceptual teaching results in poor learner performance (Akinyemi & Mavhunga, 2021). Given the above-identified problem, there was a need to conduct a study in organic chemistry to explore how the conceptual teaching strategy could be developed and implemented in teaching a section of organic chemistry by a group of selected teachers.

1.3. Purpose of the study

The purpose of this study was to explore ways in which teachers, already involved in teacher professional development within their community of practice, could collaboratively develop and implement a conceptual teaching strategy to improve the teaching of organic chemistry using a lesson study approach. In this study, lesson study refers to as an alternative format of professional development where teachers work together to plan lessons for their day-to-day teaching (Ono & Ferreira, 2010).

1.4. Objectives of the study

Three objectives guided this research work. These were:

- To investigate a group of selected teachers in Hlabisa Circuit plan when preparing to teach a section of organic chemistry before the lesson study.
- To collaboratively develop a suitable conceptual teaching strategy to teach organic chemistry through lesson study, and
- To assess teacher implementation of the conceptual teaching strategy developed through lesson study.

1.5. Background of development of research questions

The following questions were identified in sync with the objectives spelt out above:

1. What is the quality of teachers' pedagogical content knowledge in planning to teach a section of organic chemistry before the lesson study?
2. What is a suitable conceptual teaching strategy for teaching a section of organic chemistry?
3. How do teachers implement the conceptual teaching strategy developed through lesson study to teach a section of organic chemistry?

1.6 Rationale of the study

Several studies have been done in PCK/TSPCK with pre-service teachers to explore how they develop topic-specific knowledge for teaching key science topics such as stoichiometry and the particulate nature of matter (Ndlovu & Malcolm, 2022; Pitjeng-Mosabala & Rollnick, 2018) However, there is a need to engage practising teachers in other key topics in science such as organic chemistry. Practising teachers need to be exposed to a professional platform where they will discuss TSPCK in the development and enactment of conceptual teaching strategies in organic chemistry. From the evidence discussed above, it is apparent that there was a need to conduct a study on developing, implementing, and evaluating conceptual teaching strategies in organic chemistry. The lesson study approach as a teacher professional development can be useful for my school cluster as well as other clusters that are already involved in communities of practice by further developing their TSPCK. Furthermore, there is a need for teacher engagement in different strategies of teaching and learning of organic chemistry, therefore, lesson study allows that collaboration of teachers with an aim of sharing teaching and learning strategies for a specific topic or concept. This is crucial for both newly appointed and experienced teachers.

1.7 Significance of the Study.

This study has the potential to influence curriculum policy, professional practice position, and research field. Firstly, policy-makers and subject advisors can gain deeper insight into conceptual teaching approaches for inclusion in curriculum statements. Secondly, the study is likely to help both newly appointed teachers and more experienced teachers improve their lesson planning, lesson delivery, and post-lesson reflection. The lesson study approach to teacher professional development can be useful for my school cluster as well as other clusters that are already involved in communities of practic by further developing their TSPCK. Lastly, the study contributes to the literature by enhancing the understanding of conceptual teaching strategies and the use of lesson study to develop, implement, and reflect on conceptual teaching strategies.

1.8. Positionality and the Researcher

In my early years of teaching, I attended a workshop for Physical Sciences in my cluster where I saw the subject advisor and lead teachers discussing reasons for poor performance in NSC examination results. In their discussions, they mentioned common misconceptions and errors that led to poor performance. They further deliberated possible strategies that could be used by the teachers to avoid such misconceptions and errors in the future. Later on, I became one of the lead teachers, and thus when I became curious about questions set in common tests and NSC examinations, learners' responses to those questions, and common errors and misconceptions by teachers and learners in these papers. Generally, I discovered that similar errors and misconceptions were noticed yearly. Such curiosity which emanated within me caused an interest in knowing more about the solutions to counteract such recurring misconceptions and errors. Attending content workshops for Physical Sciences was inadequate for me for I intended to know more for me to be in a better position to provide correct guidance to newly appointed teachers and contribute during discussions with colleagues. I felt that I needed to be developed academically. At that stage, I had a junior degree, thus I registered for an honours degree after 13 years of obtaining my junior degree. All the above compelled me me to study beyond an honours degree, hence this dissertation.

My research interest was based on science education. Due to the vast nature of discipline and grades where this discipline is taught, my focus was driven to chemistry. But still, chemistry was too large, thus it was narrowed down to organic chemistry. I was used to working with lead teachers in preparing to facilitate content workshops for grade 12 teachers. That experience encouraged me to use such a platform to generate vast data. I believe in interpretivism for there is no single truth in a phenomenon. Such collaboration of lead teachers allowed for the construction of knowledge which was later shared with all grade 12 teachers in my cluster. This is why this study used a lesson study to collaboratively develop, enact, and evaluate the teaching of organic chemistry.

Shulman (1987) points to a special kind of teacher knowledge that effectively merges content and pedagogy, termed pedagogical content knowledge. This study allowed for collected PCK and enacted PCK.

1.9. Terms relevant to the study

Four terms are used mostly in this study; topic-specific pedagogical content knowledge (TSPCK), conceptual teaching strategy, lesson study (LS) and community of practice (CoP). These terms are described briefly in this sub-topic based on literature.

- **Topic-Specific Pedagogical Content Knowledge (TSPCK)** is the "capacity to transform concepts within a topic by packaging them for teaching" (Veal & MaKinster, 1999, p. 114).
- The **conceptual teaching strategy** is the component of TSPCK which is linked with teaching procedures, and ways of ascertaining students' understanding of the big idea (Mavhunga, 2018).
- A **lesson study** is a collective or collaborative instructional plan that focuses on developing, observing, implementing, and evaluating research lessons to counteract learners' difficulties (Coenders & Verhoef, 2019; Hume et al., 2019; Lewis et al., 2011).
- **Community of practice** is defined as gathering of group of people with an aim of sharing information and on how to cultivate an organization in order for an organization to succeed (Lockwood, 2013).

1.10. Thesis outline

This thesis consists of six chapters. Chapter 1 consists of the introduction and background of this study. In this chapter, the researcher introduced the study and explained how this study was informed and guided by existing studies.

In Chapter 2, the researcher reviewed the literature informed by constructs relevant to the phenomenon. These are (i) conceptual teaching strategy in science, (ii) issues in teaching organic chemistry, and (iii) trends in lesson study approach, and content representations as a tool to capture and portray TSPCK. This chapter concluded by introducing the theoretical framework underpinning this study, which is,PCK with a specific focus on the TSPCK construct by Mavhunga and Rollnick (2013).

In Chapter 3, the researcher discussed the research design and methodology within the interpretivism paradigm. This accounted for methods of data collection and analysis towards answering the research questions. Chapter 3 concluded by outlining how research rigour was maintained and how issues of ethics were taken into consideration in this study.

In Chapter 4, the data regarding the first research question was presented and unpacked to generate findings. The main focus of the chapter was to look into how teachers were currently engaged in lesson planning before the lesson study intervention in this study.

In Chapter 5, data pertaining to answering second and third research questions was presented and analysed. This was mainly focused on developing and enacting conceptual teaching strategies in organic reactions. The main focus was given to three big ideas, namely: (a) *an ester is a product of an acid-catalyzed condensation between alcohol and carboxylic acid*. (b) *unsaturated compounds (alkenes) undergo addition reactions*. (c) *interconversion between haloalkanes and alcohols.*

The study was concluded by Chapter 6 where further discussions were made, limitations of the study highlighted, and recommendations for future studies, curriculum policy, and professional practice were also highlighted.

CHAPTER 2

2. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Introduction

This chapter first reviewed the conceptual teaching strategies in science as it is the main purpose of the study. Furthermore, this chapter reviewed pedagogical content knowledge (PCK) in general as it is stemming from the title of this study. This chapter further reviews teaching and learning organic chemistry, focusing on organic chemistry as a curriculum topic, and issues in teaching and learning this topic. Furthermore, this chapter representstools for capturing knowledge for teaching. This study uses a lesson study approach, therefore, this chapter also reviewed the lesson study as a continuous professional teacher development and, lesson study as a research design. The lesson study was the main source of data generated in this study. Thus, the researcher reviewed its effectiveness found by other researchers. In conclusion, the construct ofTSPCK is unpacked as a theoretical framework that informs the lens for understanding the types of data to collect, the questions to ask, and the factors to investigate.

2.2. Conceptual teaching strategies in Science

The conceptual teaching strategy is one of the knowledge components in the TSPCK literature (Ndlovu & Malcolm, 2022). This knowledge component develops when teachers deal explicitly with learners' prior knowledge, the knowledge of big ideas in a topic, and effective ways of representing content when addressing students' misconceptions (Mavhunga, 2018). It is perceived that learners come to class with different understandings of concepts from the communities they live in and previous grades that commonly develop into misconceptions in science. As a result, teachers need to consider what learners know before introducing new concepts.

Bryan (2007) argued that students' misconceptions are a major concern to deal with. On the other hand, Banjo (2019, p. 33) advocated that "*learners gain a conceptual understanding of the concept when they can draw inferences or recognize relationships between learners' prior knowledge and new experiences*". Taking into consideration what these authors posited, teachers would know how to plan and enact meaningful lessons after considering students' prior knowledge, especially misconceptions.

Bravo Gonzalez and Reiss (2021) in London argued that teachers have their understanding of big ideas although there is nothing specified on how to conceptualise those big ideas. This is the gap found in this literature which requires further empirical research to address. The conceptual teaching strategy is seen as the most difficult component of TSPCK in several topics in the Physical Sciences. These topics include stoichiometry (Ndlovu & Malcolm, 2022), electrochemistry (Rollnick & Mavhunga, 2014), and chemical equilibrium (Mavhunga & Rollnick, 2013). These authors pinpoint difficulty in this component of TSPCK as its nature of amalgamating all other components of TSPCK by showing a harmony linkage.

In science education research, organic chemistry is reported as one of the difficult topics which require conceptual teaching strategies to teach it (Adu-Gyamfi & Asaki, 2023). What is of particular interest in this study are the findings made by Akinyemi and Mavhunga (2021) in their study on organic chemistry with beginning teachers. They reported that novice in-service teachers find it difficult to develop conceptual teaching strategies on the topic of organic chemistry. As a result, professional development needs to be strengthened to support beginning chemistry teachers to counteract these reported difficulties in this topic. According to Kind (2009), "*preparing high-quality teachers is an ongoing process*". Therefore, professional development is not only important for beginning chemistry teachers, but also for important for in-service teachers.

The work of Mavhunga (2018) identified gaps in TSPCK research with practising teachers, especially for lesson enactment. Research needs to be conducted to explore how practising teachers develop and enact lessons from the conceptual teaching strategies point of view. While these suggestions are made in this thesis, Ndlovu and Malcolm (2022) emphasised the need for TSPCK-structured interventions in topics considered difficult, such as organic chemistry to support beginning teachers.

Most studies on conceptual teaching strategy in organic chemistry focused on university-level contexts with PSTs (Crimmins & Midkiff, 2017; Fautch, 2015; Sibomana et al., 2020). There are also studies done in organic chemistry that dealt with other perspectives on this topic. For example, Hume et al. (2019) focused on repositioning pedagogical content knowledge in teachers' knowledge for teaching science using the case of organic chemistry, Anim-Eduful and Adu-Gyamfi (2021) focused on functional group detection where they investigate conceptual difficulties in teaching chemistry by teachers. Lastly, Adu-Gyamfi and Asaki (2022) focused on teacher's conceptual difficulties in teaching senior high school organic chemistry. Almost all these studies in organic chemistry did focus on the planning and teaching of this topic and this creates a gap in the field.

In other science disciplines, studies have been conducted in planning and enacting specific topics like Mapulanga et al. (2022). These authors focused on planning and enacting TSPCK in respiration using lesson study approach. Other studies in organic chemistry focused either on planning (Mavhunga, 2018) or enacting (Akinyemi & Mavhunga, 2021) organic chemistry topic. Debatably, there are no studies found in this literature which focused on developing and implementing conceptual teaching strategies in organic chemistry through lesson study. Teachers need a platform to collaboratively plan, enact, and evaluate organic chemistry lessons through lesson study.

2.3 Development of pedagogical content knowledge (PCK) in general

Pedagogical content knowledge (PCK) had been defined by many researchers following notion of Shulman in late 1980s. According to Rollnick and Mavhunga (2014, p. 354), "the knowledge that teachers develop with experience is personal and therefore also difficult to measure". Banjo (2019) described PCK as the concept related to the knowledge about how specific content can be understood in classroom teaching settings. This author further categorized PCK as knowledge for teachers in content and curriculum, and the knowledge of portraying that knowledge during teaching and learning situation. Based on these evidence, its clear that teachers need to develop their PCK in general as they teach. According to Kind and Chan (2019), qualifications for teachers does not guarantee their effectiveness of pedagogical knowledge as well as difference between knowing content of a specific topic versus teaching and learning of that specific topic. It is crucial that every teacher must develop the knowledge of content as well as the knowledge of teaching that specific content for a better understanding of the students. This is regarded as development of PCK within a teacher. Therefore, this section of the literature will continue to review issues in teaching and learning organic chemistry in the next section.

2.4 Teaching and Learning Organic Chemistry

Organic chemistry is one of the topics in Physical Sciences chemistry. As mentioned earlier in the background, Physical Sciences is taught as physics and chemistry in South Africa. According to Adu-Gyamfi and Asaki (2022), teachers of chemistry require a sound scientific understanding to transform the sound scientific understanding of students, otherwise, organic concepts can be difficult. This portion of the literature reviewed organic chemistry as a topic, difficulties in teaching this topic, and research trends.

2.3.1 Organic Chemistry as a Curriculum Topic

Organic chemistry is a branch of chemistry that deals with the structures, properties, and reactions of hydrocarbons (Sibomana et al., 2020). In the South African curriculum framework, organic chemistry consists of knowledge of organic molecules and nomenclature, the structure and physical properties of organic molecules, chemical properties of organic molecules and applications of organic chemistry in industry (Department of Basic Education, 2011). This curriculum scope categorised organic chemistry as one of the topics under matter and materials. It constitutes about 11.5% weighting in the grade 12 curriculum spreading over sixteen hours of the notional time.

Precisely planned lessons can guide the teachers on what they must teach at a given time. Nomenclature focuses on teaching organic molecular structures, IUPAC naming, and formulae. Structure physical property relationships focus on boiling points, melting points, vapour pressure, and viscosity. The applications of organic chemistry are combustion reactions and esterification as well as substitution, elimination, and addition reactions, including plastics and polymers (Department of Basic Education, 2011). Looking at what has been mentioned about the organic chemistry curriculum, this topic is complex, so this topic requires "*intelligent thought because the content contains many abstract concepts*" (Zondi, 2018, p. 9). In the next sections, the review focuses on exploring the difficulties linked to teaching this topic.

2.3.2 Issues in Teaching and Learning Organic Chemistry

Bravo Gonzalez and Reiss (2021) advocated that teaching science is a complex task. Each topic demands a specific conceptual teaching strategy for learners to understand it. There are specific difficulties encountered by learners in processing information given to them in organic chemistry

(Bodner et al., 2017; Duis, 2011; Sibomana et al., 2020). While focusing on these difficulties, Bodner et al. (2017, p. 1415) stated that there is a "*tendency of some students to look at organic structures as lines, letters, and numbers rather as symbols*". For instance, the presentation of organic structural formulas using a combination of symbols and hyphens, as in C-H, where C represents a symbol of the carbon atom, H a symbol of the hydrogen atom, and (-) a bond between these atoms, often confuses learners.

Danjou (2020) concurred with the assertions of Bodner and colleagues by arguing that students develop misconceptions when looking at organic molecules. "*Organic chemistry needs lots of drawings by hand; like molecules, electron movements, vectors, etc*." (Danjou, 2020, p. 3). This problem is also faced by teachers since the topic requires conceptual teaching. This assertion is confirmed by the findings of the study by Adu-Gyamfi and Asaki (2023), where some reasons for difficulties in teaching organic chemistry included among others weak foundations in chemistry teachers from high schools where they were taught, the lack of well-capacitated teachers and the way the topic was presented to them with the focus on theory instead of enquiry-based teaching.

The difficulty in teaching organic chemistry is not an issue in South Africa only. According to Crucho (2020) who conducted a study in America, organic chemistry is a tough subject, very abstract and has many concepts that are condensed. Also, in America, Guzey and Roehrig (2009) and O'Dwyer and Childs (2017) concurred with this assertion of difficulty in learning and understanding organic chemistry as well as difficulty for teachers to stay up-to-date.

Some teachers may experience such pedagogical difficulties if they do not have foundational subject matter knowledge in the topic as asserted by Adu-Gyamfi and Asaki (2023). Anim-Eduful and Adu-Gyamfi (2021) in Ghana also asserted that efficient chemistry teaching incorporates the teacher stimulating learners to link new concepts and skills into different contexts. The teacher demonstrates information of the context throughout teaching, and considers the professional demands in teaching of that topic. If students cannot relate new concepts and skills with the existing knowledge accumulated in previous grades as suggested by (Mai et al., 2021), the concepts taught would not make sense to them in their real-life situations and applications. This kind of expertise requires teachers to have a good understanding of the subject matter knowledge in the discipline

Moreover, if teachers fail to appropriately contextualise new knowledge during instruction, students may struggle to connect these concepts with their existing understanding. Additionally, if teachers lack the pedagogical expertise required for effective organic chemistry teaching, they may present new information haphazardly, leading to further confusion and misconceptions among students. This, in turn, could contribute to a perception of organic chemistry as an insurmountable barrier in chemistry education. In the next section, the focus is on research trends in teaching organic chemistry.

Lou et al. (2012) believe that teaching organic chemistry should be based on three (3) multimedia materials, namely static pictures, videos, and animations. These multimedia materials need to be incorporated into lessons as representations. Such a variety of multimedia materials leads to the conceptual teaching of organic chemistry. According to Koopman (2017), the teaching of organic chemistry requires three levels of representation namely; the macroscopic level, symbolic level, and sub-microscopic level. As mentioned above, multimedia materials also form part of these.

Further to the postulations above, appropriate analogies and illustrations must also be incorporated as advocated by Mavhunga (2018) as key in conceptual teaching for understanding. The teaching of organic chemistry requires a variety of teaching strategies. This ascension supported what Achor et al. (2010) mentioned about the use of varied forms of teaching strategies in the study of innovative teaching strategies in secondary school science in Nigeria. These authors advocated that teachers had a knowledge of content but lacked prerequisite activity-based learning which includes bringing students' prior conception before the act of teaching.

It should not be taken for granted that teachers require well-developed PCK and subject matter content knowledge to teach science conceptually (Rollnick et al., 2008). This is in line with Koopman (2017) who argued that the low level of subject matter knowledge and low PCK in unqualified or unconfident teachers in the teaching of science has a bearing in terms of how they teach chemistry topics. This is in line with what Achor et al. (2010) discovered in their study as mentioned above, that teachers had a knowledge of content but lacked prerequisite activity-based learning which includes bringing students' prior conception before the act of teaching.

In this thesis, it is argued that beginning chemistry teachers who lack SMK and PCK need to be afforded opportunities for developing these kinds of knowledge in continuous professional teacher development. Sibomana et al. (2020) considered innovative instructional strategies in organic chemistry. These authors mentioned that diagnosing students' misconceptions is one of the innovative teaching strategies, and then after that diagnosis, remedial work of addressing those misconceptions is to be done. The work of Sibomana et al. (2020) concurs with Mavhunga (2018) in identifying misconceptions in the component of TSPCK, the student's prior knowledge. Considering issues reviewed in teaching and learning organic chemistry, there must be a way of portraying the knowledge of organic chemistry. Therefore the next section discussed the content representations.

2.5 Content representations: Tools for capturing knowledge for teaching

The work of Kind (2009) reported that having a degree in teaching a subject does not assure that a teacher will teach that subject effectively. Physical Sciences teachers need to be aware of the way they portray the knowledge they have. Content representations have been found valuable by many scholars in capturing and portraying knowledge. Content representations (CoRes) are defined as tools designed to capture and unpack teachers' PCK for teaching a specific topic (Koopman, 2017; Loughran et al., 2004). CoRes are composed of 'big ideas' and specific prompts for discussing knowledge for teaching within a particular topic (Rollnick & Mavhunga, 2016). According to these authors, prompts are categorised according to each knowledge component of TSPCK. Students' prior knowledge prompts teachers to consider students' misconceptions. For curricular saliency, prompts require teachers to identify the purpose of teaching big ideas, the knowledge to be taught and the depth of knowledge to be taught in that specific topic in a grade. Also, teachers need to indicate difficulties in teaching a specific topic. Furthermore, for representations, teachers need to indicate analogies and consider three levels of representations. Lastly, the conceptual teaching strategy is all about integrating these four components into a lesson.

Conventionally, the CoRes have been used in conjunction with pedagogical and professional-experience repertoires (PaP-eRs) which are short narratives based on teachers' accounts of and reflections on teaching a specific topic (Rollnick et al., 2008). "*CoRes focuses on teachers' understandings of those aspects that represent and shape the content and contribute to the content-specific nature of PCK, while PaP-eRs are narrative accounts of practice designed to bring to life the ideas*" (Rollnick et al., 2008, p. 1369)(Rollnick et al., 2008, p. 1369)(Rollnick et al., 2008, p.

1369). These short narratives are embedded within the five components of TSPCK mentioned above in this section of the literature.

According to Gess-Newsome and Lederman (2001, p. 104), teachers must have "*knowledge of requirements for learning*" which includes "*understanding of variations in students' approaches to learning as they relate to the development of knowledge within specific topic areas*". Taking into consideration what has been done by other scholars, this study gave teachers a professional platform where they were planning on how to engage collaboratively to develop conceptual approaches to teaching. One of the ways that have recently been used for teachers to collaborate is the lesson study. Hence, the next sections of this chapter explore literature around lesson studies.

2.6 Lesson Study Approach

This part of the literature review is based on lesson study as a continuous professional teacher development (CPTD). CPTD have a great impact in contributing to current teacher practices. Above that, this section also reviewed lesson study as a research approach.

2.6.1 Lesson Study as a form of Continuous Professional Teacher Development (CPTD)

Lesson study is an approach that originated in Japan before spreading to other countries (Coenders & Verhoef, 2019; Hume et al., 2019; Lewis & Perry, 2006). These authors define lesson study as a collective or collaborative instructional plan which focuses on developing, observing, implementing, and evaluating research lessons to counteract learners' difficulties. Lesson study has been proven to impact the teachers' professional development by scholars in Japan, Europe, and other countries (Mapulanga et al., 2023; Ogegbo et al., 2019).

The definition of the lesson and the cycles conducted during lesson study has a great impact on developing teachers' PCK. Coenders and Verhoef (2019) asserted that in lesson study pedagogical content knowledge in action where teachers shared knowledge, skills and beliefs as well as strategies of teaching specific content. This author further mentioned that PCK in action occurs in planning phase as well as in enactment phase. Based on these quotes, it clear that lesson study develops teachers' PCK in specific topic in a discipline.

Lesson study has a strong foundation in mathematics (Joubert et al., 2020, p. 907), but recently, lesson study has been used in the teaching of electricity and magnetism in South Africa where it was found valuable as well (Ogegbo et al., 2019) and the lesson study by Venketsamy et al. (2022) in implementing lesson study as continuous teacher professional development in South Africa in science education. Lesson study is an example of community of practice. Lockwood (2013) defined community of practice as gathering of group of people with an aim of sharing information and on how to cultivate an organization in order for an organization to succeed. The definitions of community of practice and lesson study links when looking at its nature of collaboration of people from the same organization. Lesson study as a CTPD intervention has been found suitable within a school, with teachers outside the school in the cluster, and as well as in national conferences (Fernandez & Yoshida, 2012). This allows the integration of teaching strategies within the discipline in specific topics. Furthermore, from being used in Mathematics, the lesson study has been used in different disciplines such as Physics (Ogegbo et al., 2019), Chemistry and multidiscipline teams in the United Kingdom (Coenders & Verhoef, 2019), and Life Sciences in Zambia (Mapulanga et al., 2023).

Lesson study has impacted the development of teachers in specific topics in different disciplines as mentioned earlier. Based on the work by Mapulanga et al. (2023) in Zambia, teachers developed the knowledge of planning and enacting a topic of respiration in Life Sciences. During these professional developments, teachers were exposed to new ideas, new topics became popular, and new approaches to a specific topic. Coenders and Verhoef (2019) advocated two phases of teacher growth during lesson study: the development phase; personal, external, and material domain, and class enactment; a reflection between personal, external, and material transparencies. These domains' growth is important for every Physical Sciences teacher in all topics taught. Lesson study as a long-term professional development engagement (Baricaua Gutierez, 2016) enabled teachers to review their pedagogical methods.

Lesson study emphasised collaboration in planning and enacting lessons for a specific topic in a specific discipline. Mesci et al. (2020) in Turkey found knowledge of pre-service teachers like science enquiry (NOS) before lesson study undeveloped which was developed after the engagement in lesson study. "*Following the PCK-based NOS instruction, almost all of the PSTs demonstrated a better-developed understanding of NOS, and they successfully maintained their informed views in the long term*". This assertion confirmed the lesson study approach as teachers' professional development and as a way of growing teachers' TSPCK. Cajkler et al. (2013) concur with this assertion when they view a lesson study as a teacher's professional development and as an approach that contributes to preparing new teachers. Coenders and Verhoef (2019) found lesson study (LS) useful for both newly appointed teachers as well as experienced teachers. The next section of this review touched on lesson study as a research approach.

2.6.2 Lesson study as a research approach

Following the application of LS to various subjects by many scholars (Coenders & Verhoef, 2019; Fernandez & Yoshida, 2012; Lewis et al., 2011; Mapulanga et al., 2023), this study used the LS research approach as a tool to gain an understanding of and build solutions for teaching organic chemistry in South Africa. Scholars across the world have used the LS cycle to demonstrate how lessons are planned, implemented, observed, and evaluated (Coenders & Verhoef, 2019; Fernandez & Yoshida, 2012; Lewis et al., 2011; Mapulanga et al., 2023). Figure 1 shows the process that was followed by many scholars when using LS approach.

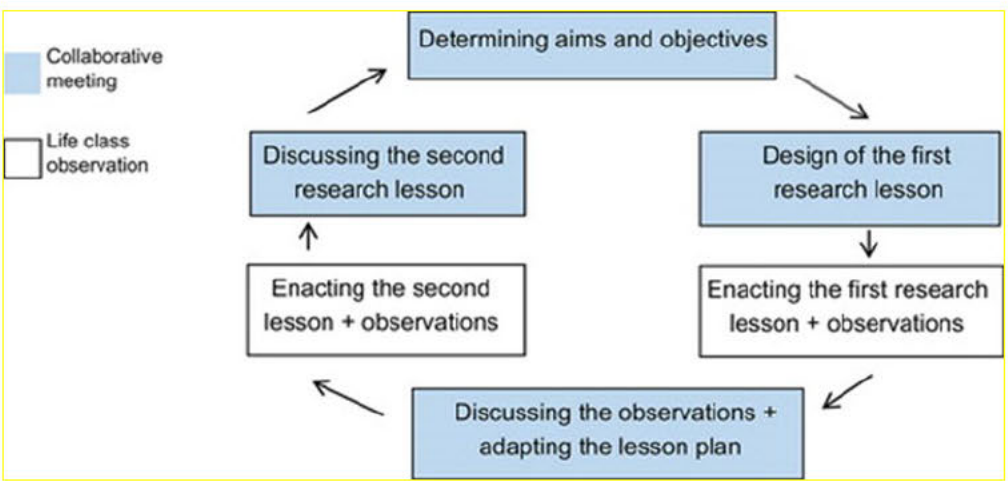


Figure 1: Lesson Study cycle (Murata, 2011)

During lesson study, teachers formulate goals for student learning, plan a research lesson, present the lesson whilst others observe it, and then reflect on the research lesson (Cajkler et al., 2013; Coenders & Verhoef, 2019). During the planning stage of the first cycle in the lesson study approach, teachers used relevant documents to determine goals for that specific topic. These documents include but are unlimited to diagnostic reports from the Department of Education and policy documents. These documents enabled teachers to identify students' misconceptions and errors during previous examinations as well as big ideas for that specific topic. According to Cajkler et al. (2013, p. 538), "*groups of teachers identify challenges faced by their learners and collectively plan a research lesson that addresses the challenge*". Based on this assertion, the challenges identified enabled teachers to formulate the goals of the research lesson. Those identified difficulties, misconceptions and errors need to be attached to an identified big idea. Lewis et al. (2011, p. 64) argue that "*teachers working in groups to examine instructional practice can produce broad, sustainable improvement*". Therefore, these identified objectives and goals allowed teachers to develop strategies that will be used during lesson enactment in a classroom setting.

According to Murata (2011), after the development of the first lesson, the lesson is enacted whilst taking note of any gaps that are found in a developed lesson and additional knowledge that arose in the first lesson enactment. This author mentioned that discussions done after the first lesson enactment gave rise to the second lesson which is also enacted at a later stage. Ogegbo et al. (2019) found challenges in the lesson study approach due to the duty load for teachers, the time factor, a lack of resources and a smaller number of Physical Sciences teachers in a school. Based on this statement, this approach can be compromised if teachers are unprepared to go the extra mile. One should be conscious of the lesson study approach as a personal development otherwise the outcry for poor performance of learners will always be encountered. According to Fernandez and Yoshida (2012), lthe esson study approach allows teachers to explore more examples in that specific topic, plan teaching, and do observation of lessons to clarify in classrooms.

2.7 Theoretical framework

This study adopted the theoretical construct of topic-specific TSPCK described by Mavhunga and Rollnick (2013). TSPCK as a theoretical construct has its roots in Shulman's idea of content amalgamation with pedagogy, as pedagogical content knowledge (PCK) and the notion of PCK taxonomies introduced by (Veal & MaKinster, 1999) to re-conceptualise PCK at a topic level. Mavhunga and Rollnick (2013) build from the subject matter transformation ideas through content-specific components which they adapted from (Geddis & Wood, 1997). The advantage of using the TSPCK theoretical construct is its propensity to pay careful attention to the learner's prior knowledge, curricular saliency, what is difficult to understand, and representations, which all lead to the development of a conceptual teaching strategy (Mavhunga, 2018). This theoretical construct will give lenses when generating data using TSPCK-based CoRe. The prompts of TSPCK will make it easier to see the roots for organic reactions and the analysis of data will be based on those roots from TSPCK-adapted CoRe. To begin with, the next paragraph revisits the original ideas around the notion of PCK as the theoretical basis for TSPCK.

2.7.1 Pedagogical Content Knowledge (PCK)

PCK was introduced in the late 1980s by Shulman (1987) as part of the seven knowledge bases for teachers. Shulman (1987, p. 7) described "*PCK as the capacity of the teacher to transform the content knowledge that he/she has into forms that are pedagogically powerful*". Other scholars further expanded from Shulman's notion to define PCK in detail. Recently, Rollnick and Mavhunga (2014, p. 367) described PCK as a knowledge of *"how teachers teach their subject by accessing what they know about the subject, the learners they are teaching, the curriculum with which they are working, and what they believe counts as good teaching in their contexts"*. Other scholars like Kind and Chan (2019, p. 1) posited that "*PCK is useful for thinking about the teachers' professional knowledge and practice, potentially contributing to an understanding of how and why teachers help students learn science"*. What is of interest in this study is the perception offered by Geddis and Wood (1997, p. 612) that "*PCK is a broad category of those kinds of knowledge bases involved in the transformation of subject matter*". These knowledge components have been the fundamental basing for describing the TSPCK construct.

2.7.2 Topic-Specific Pedagogical Content Knowledge (TSPCK)

TSPCK is defined as the teacher's ability to transform their disciplinary knowledge of the content of a given topic into formats that are suitable for teaching purposes (Mavhunga & Rollnick, 2013). The understanding of how the transformation of content knowledge comes about was presented by Geddis and Wood (1997). These authors argued that the transformation of content knowledge emerges from the considerations of several different types of knowledge which are content-specific.

These knowledge types are (i) students' prior knowledge, (ii) curricular saliency, (iii) what is difficult to teach, (iv) representations, and (v) conceptual teaching strategies (Mavhunga & Rollnick, 2013). Collectively, the knowledge of these components would then result in the transformation of concepts in a topic to make them easier to understand by the learners.

The five components make up the TSPCK construct as mentioned in the above paragraph. Figure 2 shows a refined consensus model of the TSPCK-construct. This diagram is a simplified version of the refined consensus model of TSPCK. It is taken from the work of (Carlson & Daehler, 2019) and simplified by Mavhunga (2020).

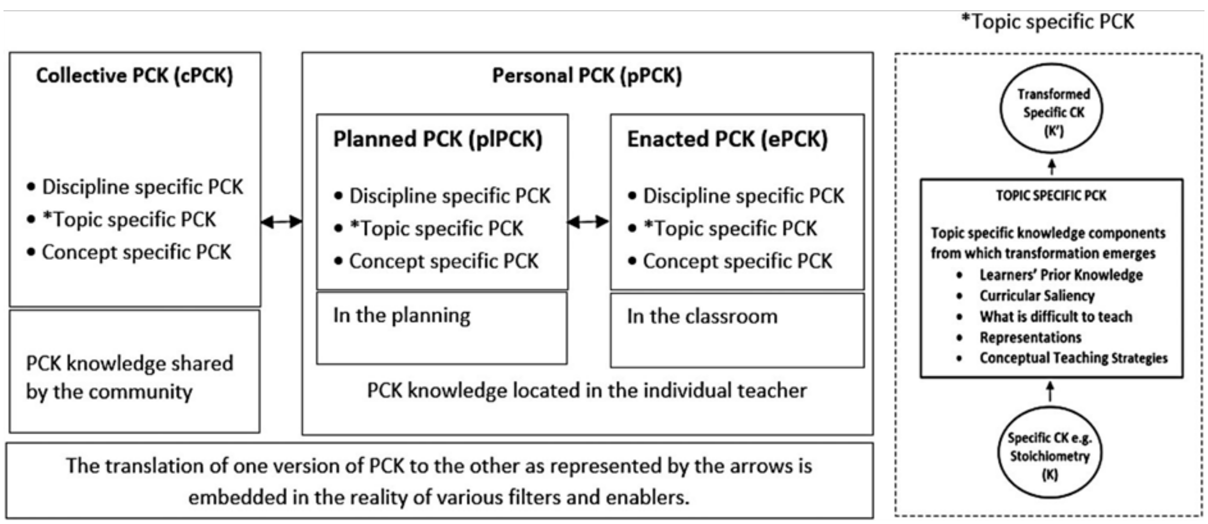


Figure 2: A refined consensus model of TSPCK

In the middle section of the model, the personal PCK (pPCK) is shown with two types of personal PCK. These are planning and enacted PCK. In the planned PCK, this is where the lesson is developed. In the enacted PCK, this is where the topic is taught in the classroom. On the far left of the model, the collective PCK (cPCK) is shown. This represents the PCK that is held in canonical with others in the field of knowledge (Smith et al., 2018). From this simplified version of the refined consensus model, this study was conceptualised on the translation from planned personal PCK into planned collective PCK which was later enacted PCK (ePCK) in classrooms. Regarding the levels of generality, this study focused on topic-specificity as mentioned above considering the five components taken from Mavhunga (2020). In the next section, each of these components is briefly explained, starting with the students' prior knowledge.

Students' Prior Knowledge

Students' prior knowledge is defined as knowledge and beliefs about a student's understanding of specific scientific concepts (Hassard & Dias, 2013). This knowledge component lays a background during the introduction of a lesson by giving awareness to the teacher on what learners know about that topic. It deals with "*knowledge about the students' thinking that influences the teaching of that idea*" (Rollnick & Mavhunga, 2016, p. 4). Rollnick and Mavhunga (2016) further highlighted that students' prior knowledge includes misconceptions that learners bring in class about the topic under discussion.

Curricular saliency

Curricular saliency is defined by Rollnick and Mavhunga (2016, p. 1367) as a "*teacher's understanding of the place of a topic in curriculum and the purposes for teaching it*". These authors further describe curricular saliency as an "*awareness of how a topic fits into the curriculum*". This component of TSPCK is linked to the consideration of what teachers intend students to know about this idea, why is it important for the students to know this and what else teachers might know about the idea that they do not intend students to know (Rollnick & Mavhunga, 2016). The work of Vokwana (2013) also supports this statement by advocating that curricular saliency influences lesson planning through the identification of aspects to be taught and the depth at which those aspects are covered. Teachers need to know the boundaries of the topic in a curriculum as a whole and the reasons for teaching that topic. That will enable teachers to know exactly what they must teach and what not to teach on a particular topic in a specific grade. It is at this component where the teachers draw a clear overview of the topic presented where teachers display their knowledge of content as well as their pedagogical knowledge.

What is difficult to teach?

According to Mavhunga and van der Merwe (2020), what is difficult to teach/understand is described as an ability to identify gate-keeping concepts within a difficult topic. Ndlovu (2017) advocates that some concepts are abstract to teach as each topic has its specific content which demands a unique approach for it to be understood by learners. Some parts of the content and or concepts can be easy to teach and other parts need a special way of teaching for learners to understand them. According to Rollnick and Mavhunga (2016), this component is linked to the prompt on 'difficulties or limitations connected with teaching that idea'. Having teachers identifying big ideas and knowing the purpose of teaching a specific topic, it is paramount to have a strategic plan foregrounded on how to address the difficult aspects of that specific topic. Vokwana (2013) advocated that this knowledge component helps teachers develop conceptual representations and teaching strategies to counteract these difficulties. Therefore, the next paragraph describes the components linked to representations.

Representations

Representations include a wide range of "*examples, illustrations, analogies, simulations, and models that are relevant to a topic*" (Mavhunga & van der Merwe, 2020, p. 71). Teachers need to understand how components of TSPCK work, not as compartments but as correlations with one another. The work of Loughran et al. (2004, p. 376) explained that "*CoRe sets and discusses science teacher' understanding of particular aspects of PCK*". This knowledge of teachers includes representations to address students' misconceptions, representations used to explain the purpose of teaching that big idea, representations used to address difficulties in a topic and representations for teaching strategies that will be followed during lesson enactment. One can conclude that this is an amalgamation of all components of TSPCK within representations. According to Koopman (2017), this component comprises three levels ,namely macroscopic, sub-microscopic, and symbolic. Physical changes are visible, for example, colour change or phase change, whilst models are used to represent particles that cannot be seen, and lastly, symbols are used for formulas (Koopman, 2017). Teachers need to show a smooth correlation in these levels for learners to understand the topic presented to them. The main purpose of representations is to reinforce specific concepts in a topic. Learners can be able to imagine the concept and relate it to the existing knowledge in their brains when representations are conceptually addressed to them. The last component is the conceptual teaching strategy discussed below.

Conceptual teaching strategy

This is the last component of the TSPCK framework. Mavhunga and Rollnick (2013) define conceptual teaching strategy as knowledge of effective instructional strategies for particular misconceptions using suitably chosen representations and incorporating well-teaching difficulties. This component comprises all other components of TSPCK (Ndlovu & Malcolm, 2022). It is at this component where "teaching procedures" and "ways of ascertaining students' understanding of an idea" are outlined (Rollnick & Mavhunga, 2016, p. 4). Most scholars describe conceptual teaching strategy as the most difficult component in different chemistry topics (Akinyemi &

Mavhunga, 2021; Ndlovu & Malcolm, 2022). This is a reason this study saw a need to collaboratively develop conceptual teaching strategies through lesson study.

During the lesson study, these teachers have to identify prior knowledge and misconceptions in organic chemistry, have a way to address what is difficult to understand in organic chemistry teaching, and integrate all three levels of representations in organic chemistry for the content to be transferred with harmony to learners. According to Akinyemi and Mavhunga (2021), conceptual teaching strategy emphasises what is important about the content and the use of representations to make content understandable. This component is the heart of the teaching of every topic presented in classroom settings. Due to the vast nature of the organic chemistry, the specific focus was on organic reactions. It has been indicated in the background that this is the most poorly performed topic in the chemistry National Senior Certificate (NSC) examination (Department of Basic Education, 2022). In concluding this theoretical framework, the focus is on lenses offered by TSPCK.

2.8. Conclusion

This literature review has shown that most studies in organic chemistry focused on university-level contexts and pre-service teachers (PSTs) research. These studies mostly explored translations of some class activities to homework activities to increase time for attending to students' difficulties, pedagogical need for teaching and learning organic chemistry, and conceptual understanding of the topic and its classroom implications.

There are still gaps in the development, implementation, and evaluation of conceptual teaching strategies through collaborative platforms such as lesson study in organic chemistry. As a result, the guiding aim of this study is to explore the development of conceptual teaching strategies in organic chemistry through a lesson study approach. Research shows that the lesson study approach has been used both internationally and locally to develop teachers in a continuous professional setting. This has been done largely in mathematics education research. We say this under correction, while one study has been done in physics using e lesson study approach, there is still a need to do more work on other topics, particularly organic chemistry.

In the next chapter, the research methodology and design that guided this study areunpacked. This unpacking is in line with the three research questions presented in Chapter 1.

CHAPTER 3

3. RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

The main purpose of this research study as indicated in the previous chapters was to develop and implement the conceptual teaching strategy using the case of organic chemistry with practising teachers. The study was informed by three operational objectives that were used to unpack the main purpose of this study. The first objective was to investigate how a group of selected teachers in Hlabisa Circuit plan when preparing to teach a section of organic chemistry before the lesson study. The secondly objective was to collaboratively develop a suitable conceptual teaching strategy to teach organic chemistry through lesson study. Lastly, the objective was to assess teacher implementation of the conceptual teaching strategy developed through lesson study. In line with these objectives, three research questions were asked and they guided this study.

Given these objectives, this chapter entails the research design and methodology that guided the overall purpose of this study. The chapter begins by revisiting the research paradigm that underpins the researcher's worldview and discusses the fitting methodology within the chosen paradigm. Subsequently, the chapter outlines the research design and the methods used to generate and analyse data to respond to the set of three research questions articulated in Chapter 1. Furthermore, the methods of data analysis used in this study are also discussed. In run down, this chapter concludes by highlighting issues about rigour and ethical considerations that applied to this research. The next section begins by unpacking the research paradigm adopted in this research.

3.2. Research paradigm

This study was conceptualised within the interpretivism paradigm. This paradigm is also seen by other scholars as constructivist in its outlook (Wahyuni, 2012). Interpretivism or constructivism as a school of thought contends that humans learn by developing an understanding of specific topics in specific contexts (Morgan et al., 2017). As a result, it assumes that knowledge consists of dynamic human constructs rather than fixed absolute truths (Morgan et al., 2017). In addition, according to Wahyuni (2012), reality is socially constructed based on humans' perceptions. Since "*human perspectives and experiences are subjective, social reality may change and can have multiple truths*". This implies that research within interpretivism can provide valuable insights into the complex and nuanced experiences of individuals and sometimes groups. This helps provide our understanding of the social and cultural factors that shape our world.

As indicated earlier above, the main purpose of this study was to develop, implement and evaluate conceptual teaching strategies in organic chemistry. This paradigm enabled this research to explore the diverse knowledge that the participating teachers bring when planning to teach the topic of organic chemistry and how that knowledge refines as they reflect on their lesson enactment. Theoretically, this reflects how teachers' PCK translate from personal to canonical PCK in organic chemistry. Furthermore, the developed conceptual teaching strategies came with a new reality since "*interpretive researchers favour to interact and to have a dialogue with the studied participants*" (Wahyuni, 2012, p. 71). As a result, this worldview provided a good ground at which the phenomenon in this study could be studied within an appropriate theoretical framework.

There is always a need to keep alignment between the research paradigm and a choice of methodology in educational research. According to Creswell and Creswell (2018), the constructivist researcher is most likely to depend on a qualitative data generation approach and analysis. Hence the next section outlines the methodology adopted in this study in line with the requirements of a constructive or interpretive paradigm.

3.3. Methodology

A qualitative research approach was followed in this study. Commonly, qualitative research is defined as words that can be recited back and forth to describe information (Smythe & Giddings, 2007). According to Aspers and Corte (2019, p. 155), "*Qualitative research is a process in which improved understanding is achieved by making new significant distinctions resulting from getting closer to the phenomenon studied*". Furthermore, qualitative research seeks to find the issue of concern in its everyday context, and through interviews, observations, or accessing text, hear the voices of those closely involved.

Predominantly, interpretive research is typically qualitative (Wahyuni, 2012), meaning that it relies on data that is collected through methods such as interviews, observations, and focus groups (Cohen et al., 2007). This type of data allows researchers to gain a deep understanding of the participants' perspectives and experiences

In this study, the participants met frequently to develop and reflect on their conceptual teaching strategies in organic chemistry, with a specific focus on big ideas around the knowledge of organic reactions. Cohen et al. (2007) further argue that a qualitative approach allows researchers to study relatively small numbers to develop an in-depth understanding of events, actions, and unique circumstances. Within Cohen and colleagues' description, this was focused only on four participants who met regularly to plan and reflect on the conceptual teaching of the topic. These meetings were descriptive-laden and informed by exhaustive reflections on teaching organic reactions by individual teachers. This provided thick descriptions of how conceptual teaching strategies developed and how they were implemented by the participating teachers.

Given the above, the qualitative research approach was preferred in this study because of its nature of constructing new knowledge within the context. Several approaches are linked to qualitative kind of research, for example, case studies, ethnographic research, life histories, action research, participatory research and phenomenological studies, to mention a few (Bertram & Christiansen, 2014). Given the main purpose of this study and the nature of the research questions asked, the most suitable research method adopted was a case-study design with the elements of the lesson study approach. Hence, in the next section, the research design that was followed in this study is unpacked.

3.4. Research design

This research followed the lesson study approach through a single case study of teachers in Hlabisa Circuit who collaboratively worked together in developing and implementing a conceptual teaching strategy for teaching a section of organic chemistry. The lesson study approach enabled this study to explore teachers' understanding of a phenomenon, meaning planning, teaching, and reflecting on conceptual teaching strategies in organic chemistry.

In literature, some scholars have used lesson study cycles to demonstrate how lessons can be planned, implemented, observed, and evaluated (Coenders & Verhoef, 2019; Murata, 2011). As such, this study has used the lesson study cycles to engage four Physical Sciences teachers, including the researcher in the cluster for this study. As pointed out earlier, this lesson study was embedded within a single case study research design.

Case study as a research design is a wide-ranging technique that uses many sources of data to account for complex phenomena in a real-life situation (de Vries, 2020; Morgan et al., 2017). Furthermore, Yin and Campbell (2018, p. 46) assert that in a case study, the researcher "*investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be evident*".

In this study, the selected Physical Sciences teachers who were participants were already teaching this subject in grade 12, using the national curriculum and assessment policy framework to plan and teach science. This meant that the study took place in a real-life context and the boundary between the study and the phenomena was blurred. Furthermore, in the case study, the aim is to respond to the questions about 'how' and 'what' questions about conceptual teaching strategy in the section on organic chemistry. These questions were both theoretical and descriptive. Since organic chemistry is a very large topic in the curriculum envelope, the case in this study was based only on conceptual teaching strategy in organic reactions since it is the most challenging topic reported in the diagnostic report by the Department of Education. The development of the conceptual teaching strategy followed two cycles of a lesson study (explained in Section 3.6 below). The next section outlines the process and methods used in selecting research participants in this study.

3.5. Research Participants

3.5.1 Selecting participants

A purposive sampling technique was used to select the research participants in this study. Purposive sampling, according to Etikan et al. (2016, p. 1), is a non-probability sampling technique where a "*researcher has something in mind and participants that suit the purpose of the study is included*". This study was conducted in Hlabisa Circuit in uMkhanyakude District in northern KwaZulu-Natal. Participants were selected purposively on the basis that they are qualified to teach Physical Sciences and t they have experience in planning and teaching organic chemistry lessons at the grade 12 level. Another criterion considered in selecting participants was convenience. According to Stratton (2021), convenient sampling is a non-probability sampling technique where participants are selected by a researcher because they are convenient and easy to access. Thus, only teachers belonging to an operational Physical Sciences cluster were selected. Therefore, the selected teachers were already part of a cluster that plans and teaches Physical Sciences together.

3.5.2 Describing the Participants

The four selected teachers out of twenty teachers, two females, and two males were selected because they have qualifications in teaching a subject and have over ten years of experience in teaching the subject. Moreover, they used to be senior markers and deputy chief markers in the marking of the National Senior Certificate Examination for Physical Sciences in previous years. Their ages ranged between 35 and 55 years and they all worked as departmental heads in their respective schools in the same cluster. These teachers stayed closer to each other in a manner that they can meet at their convenient.

3.6. Unpacking the lesson study

Data was generated through three lesson study cycles to understand the development and implementation of the conceptual teaching strategy in organic chemistry. There were seven stages embedded in the three lesson study cycles. As pointed out earlier above, the research took place in Hlabisa circuit in one of the Physical Sciences clusters during content workshops for Physical Sciences teachers. This cluster is operational, focusing on developing and reflecting on other topics in this subject. The phases of each cycle are explained below and the activities that took place in each cycle.

Cycle I:

i) Planning: Designing the First CoRe

The four participating teachers determined the aims and objectives of teaching a section of organic chemistry. In the first meeting, the participating teachers were introduced to a TSPCK-based CoRe (topic-specific pedagogical content knowledge Content Representation) data generation instrument (Appendix A). This instrument originates from the work of Loughran et al. (2004) and was later adapted by Rollnick and Mavhunga (2016) to reflect the components of TSPCK. This adapted CoRe was used as a planning mechanism to portray the teacher's knowledge of teaching a section of organic chemistry. The final product captured by the CoRe represented the developed conceptual teaching strategy.

These participating teachers used the DBE's CAPS document in Physical Sciences, examination guidelines, and examiners' reports at this stage to determine and agree on the choice of their big ideas. They collaboratively determined the following big ideas under organic reactions, namely: (i*) alkanes are our most important fossil fuels, (ii) an ester is a product of catalysed condensation reaction between an alcohol and a carboxylic acid, (iii) unsaturated compounds (alkanes) undergo an addition reaction, (iv) saturated compounds (haloalkanes, alcohols, and alkanes) undergo elimination reaction, and, (v) Interconversion between alcohols and haloalkanes.*

From these five big ideas linked to the knowledge of organic reactions, this study reports on three big ideas, notably, (i) *an ester is a product of a catalysed condensation reaction between an alcohol and a carboxylic acid, (ii) unsaturated compounds (alkanes) undergo an addition reaction, and (iii) Interconversion between alcohols and haloalkanes.*

ii) Enacting the first CoRe-based lesson plan and observations

In the second phase of the first cycle, one teacher from the four participating teachers who were planning collaboratively presented the first developed CoRe-based lesson at a time in a classroom setting whilst the researcher was observing and audio-recorded the lesson.

iii) Discussing the observations from the first lesson

After the first CoRe-based lesson was presented, all four participating teachers met to discuss the lessons presented. Recordings were played to four participants to identify any additional information required for the teaching of organic reactions. Participants then made some additions to the first Core-based lesson. These discussions and improvements birthed the second CoRe-based lesson. These discussions were also audio-recorded to provide insights into the reflection of the first lessons. The discussions of this phase were important in informing the second cycle.

Cycle II: Improving the First CoRe-based lesson plan to a second CoRe-based lesson plan

The cycle was repeated as shown above but instead of determining goals, the second CoRe was improved from the reflections of the first cycle. The discussions and improvements made in this cycle gave rise to the third CoRe-based lesson. Figure 3 shows the lesson study cycles followed during the development and implementation of the conceptual teaching strategy (CTS).

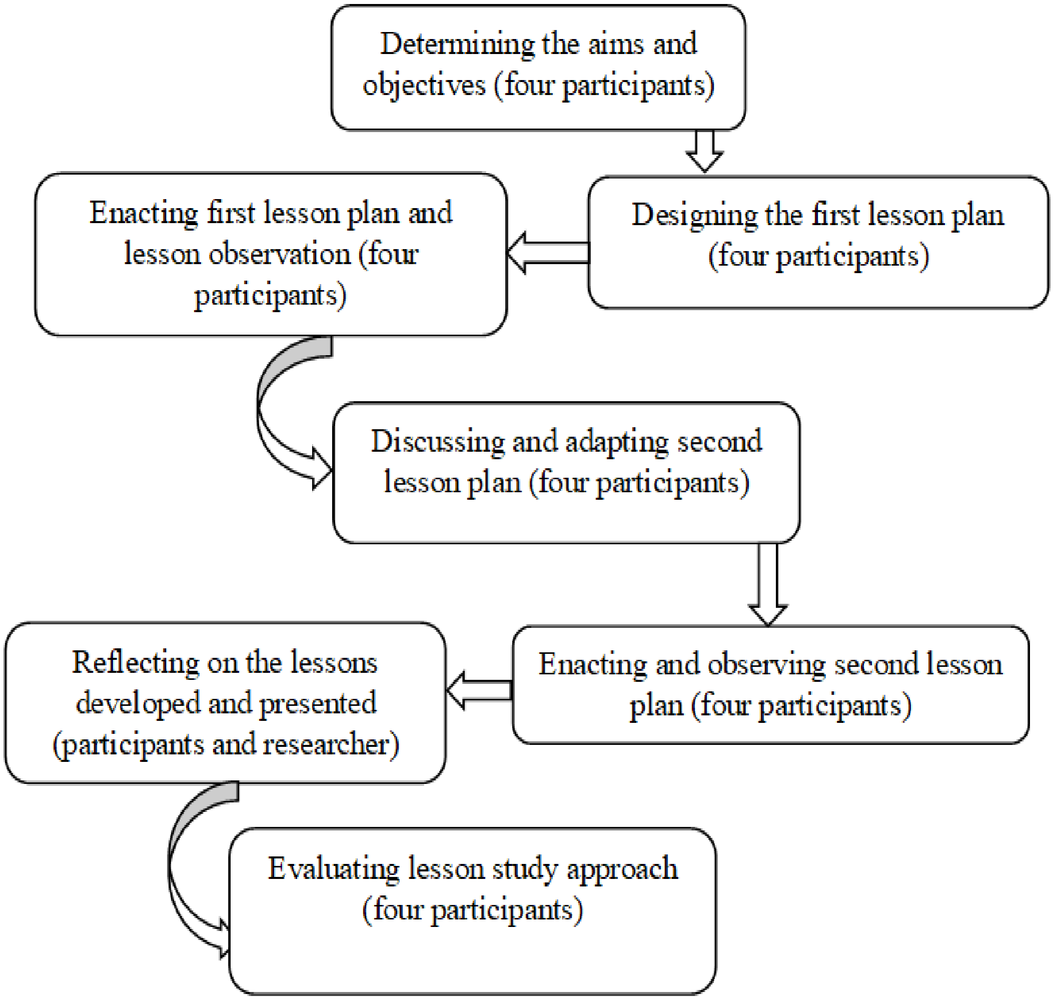


Figure 3: Lesson study cycles for developing and implementation of CTS

3.7. Data Generation

The first set of data was generated in March 2023 from the teachers' lesson plans before the lesson study. The other sets of data towards the development of the conceptual teaching strategy were generated in April 2023 through the use of the TSPCK-based content-representations (CoRes), (see Appendix A for the template) lesson plans during the lesson study. In line with the set research questions, Table 1 below shows the instruments that were used and the rationale for each question.

Table 1: Summary of the data collection process

Research Question	**Instrument**	**Data generation method**	**Type of data generated**
How does a group of selected teachers in Hlabisa Circuit plan when preparing to teach a section of organic chemistry before the lesson study?	Documents in the form of previous lesson plans from the four participants	Document collection	Transcripts of the previous lessons before lesson study
What is a suitable conceptual teaching strategy developed by a group of selected teachers through lesson study for teaching a section of organic chemistry?	TSPCK-based CoRe	Completing the TSPCK-based CoRe; Cellphone recordings	TSPCK-Based CoRe Transcripts and recording transcripts
How do teachers implement the conceptual teaching strategy developed through lesson study to teach a section of teaching grade organic chemistry?	Observation schedule Reflective questionnaire	Cellphone recordings	Transcripts

Various resources for teaching were part of the data, for example, the CAPS document for Physical Sciences and examination guidelines for Physical Sciences. These documents allowed the researcher to search for the way teachers use the content to plan and implement for a specific topic, in this case, organic reactions.

The researcher obtained qualitative data determined by the five content-specific components of topic-specific pedagogical content knowledge (TSPCK) using the CoRe mentioned earlier in the review adopted from the works of Rollnick and Mavhunga (2016). The lessons observed were recorded using a cell phone to capture important episodes in the teaching process.

In addition, data was also generated through a questionnaire from participating teachers after the lesson study cycles using a reflective questionnaire (see Appendix D). Three open-ended questions were asked to generate information to reflect on the lesson study approach. The diverse data types enabled in-depth exploration of the knowledge that teachers had on the teaching of a section in organic chemistry.

3.8 Data Analysis

The process of data analysis happened in three stages. The first data was geared towards understanding how teachers were engaged in lesson development before lesson study. The second stage looked at the development of the conceptual teaching strategy and the last stage considered the implementation of the conceptual teaching strategy. In this section, the data analysis for each stage is unpacked.

3.8.1 Teacher's Planned Knowledge for Teaching

Before the lesson study, the four lesson plans collected from participants were analysed using the TSPCK rubric (see Appendix B). This TSPCK rubric was taken from the works of Ndlovu and Malcolm (2022) with PSTs planned knowledge of teaching stoichiometry. A rubric is designed with components of TSPCK. Above that, these components are described to increase knowledge and understanding of each component and how each component is integrated into other components (Ndlovu & Malcolm, 2022). The rubric has four responses per component knowledge scaling from 'limited', 'basic', 'developing', and 'exemplary' knowledge that meets the degree of TSPCK component knowledge. This rubric was designed to increase knowledge per component indicated with a Likert scale from 1-4. Table 2 is an extract of the TSPCK rubric describing the categories of performance in the component of teaching strategies.

Table 2: An extract of teaching strategies

	Limited (1)	**Basic (2)**	**Developing (3)**	**Exemplary (4)**
Teaching strategies	• No evidence of acknowledgement of the students' prior knowledge and misconceptions. • Lacks aspects of curriculum saliency • Use of representations limited to macroscopic or symbolic or scientific symbolic representations.	• Acknowledges students' misconceptions verbally with no corresponding confrontation strategy. • Lacks curricular saliency. • Use of macroscopic and symbolic representations with no linking explanatory notes.	• Considers confirmation and confrontation of students' prior knowledge and/or misconceptions. • Considers at least one aspect related to curricular saliency e.g. sequencing or what not to discuss yet or emphasis on important concepts. • Uses at least two different levels of representations to enforce understanding.	• Consider students' prior knowledge and evidence of confrontation of misconceptions. • Considers at least two aspects related to curricular saliency: sequencing what not to discuss of important conceptual aspects etc. • Use either the macroscopic or symbolic representation with sub-microscopic representation to enforce understanding and may show awareness of learner difficulty

3.8.2 Developing the Conceptual Teaching Strategy

As mentioned earlier, the TSPCK model was employed as an analytical framework towards the development of the conceptual teaching strategy in organic chemistry. The advantage of using the TSPCK theoretical construct is its propensity to pay careful attention to the learner's prior knowledge, curricular saliency, what is difficult to teach, and representations, which all lead to the development of a precise conceptual teaching strategy (Mavhunga (2018). The data collected from the CoRes was structurally analysed using the same framework and the development of the conceptual teaching strategy was analysed from the TSPCK perspective.

3.8.3 Implementing the Conceptual Teaching Strategy

This stage of lesson implementation occurred twice during lesson study cycles. Data was analysed in both stages using the enacted-TSPCK rubric taken from Mapulanga et al. (2023) (see Appendix C). The rubric is structured according to the ten CoRe prompts reflective of the five components of TSPCK. Each prompt is described in increasing knowledge of lesson enactment and how the teacher integrates other components of TSPCK within that prompt. The performance categories in this rubric include 'very limited', 'limited', 'basic', 'developing', and 'exemplary' knowledge of enacting the collective lesson plan. These descriptions from 'very limited' to 'exemplary' illustrate the progression from one response to another and were analysed with a Likert scale from 0-4. Table 3 is an example of an extract of the components of representations.

Table 3: An extract on a prompt under curricular saliency

Prompt	Very limited	Limited	Basic	Developing	Exemplary
	0	1	2	3	4
What do you intend students to learn about this idea?	Not answered	Identified concepts are key ideas or a mix of key ideas and subordinate ideas	At least one identified concept indicates the science content to be learnt	Two or more identified concepts indicate the science content to be learnt	All identified concepts indicate the science content to be learnt

3.9 Research Rigour

Four factors, namely credibility, transferability, dependability, and conformability, determine the trustworthiness of qualitative research (Hadi & José Closs, 2016; Shenton, 2004; Sikolia et al., 2013). All these factors were considered in this study through different data generation tools. These factors are explained briefly below.

3.9.1 Credibility

Sikolia et al. (2013) define credibility as the true image of the phenomenon presented, which is equivalent to internal validity in quantitative research. The credibility of the proposed study was obtained through consistency in data collection. The credibility of this study was enhanced by the use of different sources, such as lesson plans, cell phone recordings, and open-ended questions to collect data. The next factor looked at was transferability, which is described shortly below.

3.9.2 Transferability

Transferability in a qualitative study, which is equivalent to the external validity of a quantitative study, is defined as the applicability of the findings (Campbell et al., 2020; Sikolia et al., 2013). Since the participants of this study have been clearly described in the methodology section, the findings of the study will be transferable to other Physical Science teachers. The way data was generated and analysed using the instruments outlined above, further ensured the transferability of the study's findings. Also, the national curriculum policy statement for Physical Sciences as well as examination guidelines used in this study allowed transferability to other Physical Sciences teachers since these are national policies used by all teachers in planning and enacting lessons in this discipline. The next factor articulated is dependability.

3.9.3 Dependability

Shenton (2004) posits that it is not easy to confirm a study's dependability, even when a researcher has done all s/he can to enable a future researcher to continue with the study. One way to ensure dependability is to use well-established sampling strategies (Campbell et al., 2020). The selection of participants used in this study was tried, tested, and recommended by many scholars (Coenders & Verhoef, 2019; Lewis et al., 2011). Furthermore, all the instruments used to generate data for this study were bound and preserved together with the findings to enable future investigations to replicate the study. Due to the vast nature of the topic, other big ideas were not analysed, thus providing the continuation of this study. The other factor discussed was confirmability.

3.9.4 Confirmability

Confirmability is when another researcher using the same data can obtain the same findings as the original study, thus confirming the original findings (Sikolia et al., 2013). All instruments used in this study were bound and preserved to enable other researchers' excess should they wish to confirm my findings. Recordings were preserved in a cloud account so that when the device was crushed, this information was kept. Other data in the form of documents were kept in a file for future access. Above these factors of research rigour, the researcher considered ethical issues. The next section elaborates on how ethical issues were considered in this study.

3.10 Ethical considerations

Ethical considerations are of paramount importance in an academic study as they ensure the confidentiality of participants (Arifin, 2018). Every scholar needs to consider ethics in any study conducted, *"Ethics guides and controls people and activities associated with the educational institutions"* (Khan, 2016, p. 2). In considering this quote, the Department of Basic Education in Kwa-Zulu Natal (KZN-DBE) was requested to grant ethical clearance to conduct a study in schools under this province. This was done because participants worked for KZN-DBE. The DBE clearance certificate is attached as Appendix F.

The circuit manager of Hlabisa Circuit was also requested to grant permission to use grade 12 teachers from the selected schools as part of the study. This was done because these participants report to this circuit, the consent from the circuit manager is attached as Appendix G.

The grade 12 teachers selected to participate in the study were also requested to give informed consent to voluntarily participate in the study as a contract between the researcher and participants (Fleming & Zegwaard, 2018). Participants were informed of their right to participate voluntarily, thus they were not compelled to be part of the project (see Appendix E for informed consent and invitations to the participants).

According to Fleming and Zegwaard (2018), human ethics need the explicit approval of all concerned. Therefore, these participants were given a specific venue where they were not intimidated and allowed to explore the information they had in organic reactions. Furthermore, teachers were not compelled to participate in this study although they were made aware of the value of the study. Educational scholars need to "*enrich goodness among fellow beings*" (Khan, 2016). Based on this quote, teachers were informed verbally and in writing of their rights to privacy, anonymity, and protection from reprisal. Moreover, no incentives were given to participants, as they were participating voluntarily. Schools were not negatively exposed and confidentiality was prioritised when analysing data. When requesting Physical Sciences teachers to participate, the aim and objectives of the study were honestly explained. Therefore, there was no risk in this study as participants were protected from any discomfort, be it physical or mental. To prioritise confidentiality, the names of teachers and institutions were replaced by pseudonyms.

When using secondary sources, plagiarism was avoided by providing citations of all documents used (Khan (2016). Teachers were requested to give access to lesson plans to have an insight into the teachers' planned knowledge of organic chemistry before an intervention of lesson study. Original documents were scanned to ensure that schools and individual participants did not lose their documents. Lastly, school photocopying machines were not used to benefit the study.

3.11 Conclusion

This chapter has unpacked the methods followed in undertaking this study. It also presented how the participants were selected and the reasons for selecting them. The steps followed in conducting the lesson study approach were captured. The tools used to analyse data responding to each research topic are described clearly as well.

In the next chapter, the focus will be on teachers' planned knowledge of how to plan to teach organic chemistry. This analysis is informed by the data collected before the lesson study intervention.

CHAPTER 4

TEACHERS' PLANNED KNOWLEDGE FOR TEACHING ORGANIC CHEMISTRY

4.1 Introduction

The main purpose of this study was to explore ways in which teachers, already involved in teacher professional development within their community of practice, could collaboratively develop a conceptual teaching strategy to improve their knowledge for planning, enacting, and reflecting on teaching organic chemistry. To realise the main purpose, the first objective of the study was to investigate content knowledge for teaching and strategies used by four participating in-service teachers when planning to teach organic chemistry. This investigation was conducted before the implementation of the lesson study. In line with this objective, the corresponding research question asked: *What is the quality of teachers' pedagogical content knowledge in planning to teach a section of organic chemistry before the lesson study?* As a result, this chapter presents the data collected in response to the first research question indicated above. The data for this purpose was then collected from the four participating teachers from different schools in the same circuit.

As mentioned in Chapter 3, this data was collected in the form of lesson plans that outlined the planned knowledge for teaching a particular topic. In particular, the case of organic chemistry was used for this purpose. However, due to the vast nature of the topic, the focus was given to organic reactions with the focus on one big idea for this chapter, that is '*unsaturated organic compounds undergo addition reactions'* to gain insights into how they were engaged in lesson planning.

To analyse how teachers plan to teach this idea, the study adopted TSPCK as a theoretical and analytical framework for structural qualitative analysis of planned knowledge for teaching. The TSPCK framework provided the five components, namely students' prior knowledge, curricular saliency, what is difficult to teach, representations, and conceptual teaching strategies (Mavhunga & Rollnick, 2013) as theoretical lenses for data analysis. There are different variations of TSPCK reported in the literature (Mavhunga & van der Merwe, 2020). In this chapter, the focus was given to the planned TSPCK, which is the knowledge that teachers generally use to plan to teach their lessons.

4.2 Overall Planned TSPCK for Teaching the Topic

The analysis of lesson plans collected for this phase was done through the use of a TSPCK rubric (see Appendix B) that reflects the categories for the quality of TSPCK in a planning episode. This rubric was taken from Ndlovu and Malcolm (2022). The rubric has a Likert scale of 1 – 4, reflecting the quality of TSPCK per component. The quality of this knowledge to teach in this study was analysed similarly to the work of Park and Chen (2012) who mapped the extent of PCK through component interactions.

As indicated earlier, the rubric reflects the ordinal scores describing the developing quality of TSPCK from 'limited' to 'exemplary' component interaction. These scores were averaged per component and per person to get the overall TSPCK score. The average scores are not understood to represent the statistical quality of TSPCK through mathematically mixing/integrating the components but they are a proxy of the overall qualitative quality observed from lesson planning by the participants. Thus, each lesson plan was analysed for the quality of TSPCK in each component using the same rubric. In Table 4.1, the ordinal scores reflecting each participant's TSPCK in each component are shown.

Table 4: TSPCK ordinal scores for planning to teach addition reaction

	SPK	CSA	WDT	REP	CTS	Person Average
Peter	1	1	1	1	1	**1**
Mary	1	3	1	1	1	**1**
Jane	1	1	1	1	1	**1**
Thabo	1	2	1	1	1	**1**
Component Average	**1**	**2**	**1**	**1**	**1**	**1**

The data presented in Table 4 shows that participating teachers had limited knowledge of planned TSPCK on average in this big idea. In the same way, on component average, the component of student's prior knowledge (SPK), what is difficult to teach (WDT), the representation (REP), and conceptual teaching strategy (CTS) was found to be limited with an average score of 1. On the other hand, the knowledge of curricular saliency (CSA) was found to be basic with an average score of 2. The data presented in Table 4.1 was not analysed to make any statistical inferences or claims mentioned above. This was important to get the proxy of the quality of planned TSPCK by participants across the components and in totality. In the next sections, each of these TSPCK components is used to show how each participant's score was achieved from the analysis of the lesson plans. The first component is the student's prior knowledge.

4.2.1 Students' Prior Knowledge

The first component that was analysed was students' prior knowledge. Rollnick and Mavhunga (2016) pointed out that students' prior knowledge includes the knowledge of misconceptions that learners bring in class about the topic under discussion. Furthermore, this knowledge component includes teachers' awareness of common errors in the topic, alternative conceptions, and knowledge learnt from previous topics and grades (Ndlovu, 2017). To analyse this knowledge, Table 5 shows an extract from the TSPCK rubric that shows progressions in the knowledge of TSPCK.

Table 5: An extract from the CoRe rubric on students' prior knowledge

	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
Students' Prior knowledge	• No identification/ No acknowledgement/no consideration of students' prior knowledge or misconceptions. • No attempt to address the misconceptions.	• Identifies misconceptions or prior knowledge. • Provides a standardized definition as a means to counteract the misconception. • No evidence of drawing on other TSPCK components.	• Identifies misconceptions and prior knowledge. • Provides standardized knowledge as a definition. • Expands and re-phrases explanation using the other component of TSPCK interactively.	• Identifies misconceptions or prior knowledge. • Provide standardized knowledge as the definition • Expands and re-phrases explanation/ conforms accurate understanding, drawing on interactively two or more other components of TSPCK.

Before the lesson study, the analysis of the lesson plans revealed that the participating teachers only focused on the knowledge concepts learnt from previous topics as students' prior knowledge. These are reflected in the following extracts. Figure 4 was extracted from Peter's lesson plan.

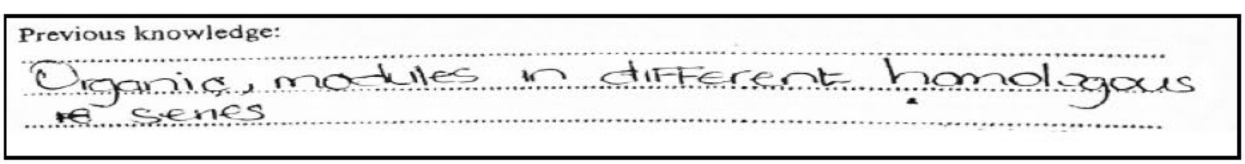

Previous knowledge:
Organic, modules in different homologous series

Figure 4: Extract of student prior knowledge from Peter's lesson plan

Figure 4.1 shows an extract of students' prior knowledge from Peter's lesson plan. Peter mentioned that students should know 'organic modules in different homologous series'. This is the knowledge from previous sections learnt in the same grade under organic chemistry. The response by Peter indicates just an awareness of previous knowledge taught. As much as this part of students' prior knowledge, a large portion in the description of prior knowledge was not given attention such as misconceptions, common errors and alternative conceptions, to mention a few.

Similarly, Mary was also aware of this knowledge component of students' prior knowledge. Figure 5 shows how Mary indicated the knowledge of students' prior knowledge from her lesson plan.

PREVIOUS KNOWLEDGE: hydrocarbow , saturated and unsaturated compounds . Structural formulers

Figure 5: Extract of students' prior knowledge from Mary's lesson plan

The lesson plan for Mary indicated an awareness of students' prior knowledge through the knowledge of previous concepts taught on the same topic, and these include the knowledge of hydrocarbons, saturated and unsaturated compounds, and structural formulas. Just like Peter, the knowledge of misconceptions, common errors, alternative conceptions, and the knowledge that has been learnt from previous grades was not evident in Mary's lesson plan as shown in Figure 5

Figure 6 shows another response by Jane on the same knowledge component. Just like Peter and Mary, her focus was also on knowledge learnt from other topics in the same grade about the formation of esters through a catalytic condensation reaction of alcohols and carboxylic acids (see Figure 4.3, an extract from her lesson plan).

PREVIOUS KNOWLEDGE: LEARNERS KNOW HOW ESTERS ARE FORMED

Figure 6: Extract of students' prior knowledge from Jane's lesson plan

What is observed from all these three responses, the participating teachers identify different concepts learnt from the previous section. There were no similarities. Notably, the fourth respondent, Thabo, did not identify any aspects of students' prior knowledge in his lesson plan. The findings above reveal that the participating teachers had very limited knowledge of this component as part of their planned knowledge to teach. The following paragraph analyses the second component of TSPCK, curricular saliency.

4.2.2 Curricular saliency

From the theoretical framework, curricular saliency is the component that considers the knowledge of (i) the big ideas that make up the topic, (ii) what teachers intend students to learn from that idea, (iii) why is important for students to know that idea, and (iv) what else the teachers might know about that idea that they intend their students not to know yet (Rollnick & Mavhunga, 2016) (see Table 6, an extract from the CoRe rubric).

Table 6: An extract from the CoRe rubric on curricular saliency

	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
Curriculum Saliency	• Identified concepts are a mix of Big Ideas and subordinate ideas. • Identified pre-concepts are far from the topic.	• Identifies at least 3 Big Ideas. • Not all 3 Big Ideas' subordinate concepts were identified. • Suggested sequencing has one or two illogical places of Big Ideas. • Identified pre-concepts are far from the current topic. • Reasons given for the importance of the topic exclude conceptual considerations and show no evidence of drawing on other TSPCK components.	• Identifies at least 3 Big Ideas. • Subordinate concepts are correctly identified for all Big Ideas. • Provides logical sequence. • Identifies pre-concepts relevant to the topic. • Reasons given for the topic the importance include reference to conceptual scaffolding/sequential development drawing on one other TSPCK component.	• Identifies at least 3 Big Ideas. • Subordinate concepts correctly identified for all Big Ideas with explanatory notes. • Provides a logical sequence of all 3 Big Ideas and logical reasons. • Identifies pre-concepts relevant to the current topic and explanations are given. • Reasons given for the importance of the topic include conceptual scaffolding concerning other TSPCK components. e.g. learner's prior knowledge and what makes it difficult.

From the analysis of the four lesson plans, two teachers, Mary and Thabo, showed awareness of the aspects of curricular saliency. To begin with, Mary indicated what she intended her students to learn about the big idea, that: 'unsaturated compounds (alkenes) undergo addition reactions'. In addition to this, Mary provided a logical sequence of key ideas that she planned to teach. Furthermore, the pre-concepts or subordinate ideas relevant to the key idea topic and their explanations were given as per the description of the component of curricular saliency. The key concepts mentioned were: hydrohalogenation is an addition reaction of HX to an alkene (X=Cl, Br or I); halogenation is an addition reaction of X_2 to an alkene; hydration is an addition reaction of H_2O to an alkene, and hydrogenation is an addition of H_2 to an alkene. Figure 7 shows an extract from Mary's pre-lesson study lesson plan.

CONTENT: Unsaturated compounds (alkenes) undergo addition reactions. Hydrohalogenation is an addition of HX to an alkene (X = Cl, Br or I). Halogenation is an addition of X_2 to alkenes. Hydration is an addition of H_2O to alkene. Hydrogenation is an addition of H_2 to an alkene

Figure 7: Extract of curricular saliency from Mary's lesson plan

As much as Mary indicated key aspects of curricular saliency, there was no indication of why it was important for students to know about this idea and what else Mary might know about this idea that she intended students not to know yet.

On the other hand, Thabo also showed an awareness of some aspects of curricular saliency. However, for Thabo, the emphasis was on the objectives of the lesson, that is, explaining what is intended to be learnt or taught within that big idea. As much as Thabo outlines what is to be learnt, the big idea is not explicitly mentioned in his lesson plan. Similar to Mary, there was no indication of why students needed to know that idea, and what else he might know about that idea that he intended students not to know yet. Figure 8 shows an extract from Thabo's pre-lesson study lesson plan

OBJECTIVES

- Learners will be able to identify changes that can be made in saturated and unsaturated hydrocarbons.
- Learners will be able to identify types of addition reactions.
- Learners will be able to use structural formulae to a balance addition chemical reaction.

Figure 8: Extract of curriculum saliency from Thabo's lesson plan

Summarily, for curricular saliency, Mary showed developing knowledge and Thabo showed basic knowledge of curricular saliency in addition to reactions. Meanwhile, for the other two respondents, Peter and Jane, there was no indication of the knowledge of curricular saliency in their pre-lesson study lesson plans. In the next paragraph, the focus is given to the third component of Topic-Specific PCK which is about the knowledge of 'what is difficult to teach'

4.2.3 What is difficult to teach?

According to Rollnick and Mavhunga (2016), the knowledge of "what is difficult to teach/understand" is described as an ability to identify gate-keeping concepts within a topic that are difficult to understand and why they are difficult to understand (see Table 7).

Table 7: An extract from the CoRe rubric on what is difficult to teach

	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
What makes the topic difficult?	• Identifies broad topics without reasons and specifies the actual sub-concepts that are problematic.	• Identifies specific concepts but provides broad generic reasons such as 'abstract'	• Identifies topic concepts leading to learner difficulty. • The reasons given relate to one other TSPCK component.	• Identifies specific concepts with reasons linking to specific gatekeeping concepts and TSPCK components such as prior knowledge and aspects of curricular saliency.

The analysis of all pre-lesson study lesson plans revealed that there was no awareness of this knowledge component of TSPCK by all the participating teachers. The fourth component was about the knowledge of effective representations to be used when teaching the big idea.

4.2.4 Representations

The knowledge of representations includes a wide range of "*examples, illustrations, analogies, simulations, and models that are relevant to a topic*" (Mavhunga & van der Merwe, 2020). According to Koopman (2017), this component is composed of three levels of representations, namely macroscopic, sub-microscopic, and symbolic levels. As a result, the analysis of this knowledge component was based on these descriptions (see Table 8, an extract from the rubric).

Table 8: An extract from the rubric on representations

	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
Representations	• Limited to use of only macroscopic (analogies, demos, etc.) representation with no explanation of specific links to the concept presented.	• 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 scientific symbolic representation with explanatory notes linking the two representations to the aspect(s) of the concept being explained. • Use of the above representations in combination concerning other TSPCK components. e.g. learner prior knowledge.	• Use of macroscopic representation with sub-microscopic representation to enforce a specific aspect. • Explicit link to other components of TSPCK e.g. emphasis on a core aspect of CK demonstrated in the representations and learner prior knowledge.

Peter presented the lesson in the form of a set of instructions. There was no indication of the aspects of representations that would be used. As such, it was difficult to describe the variety of the levels of representation incorporated in his lesson. Thus, it was found that Peter was unaware of the aspects of representations and specific levels of representations used in chemistry. Figure 9 shows how Peter intended to explain concepts in his lesson; the explanations are completely verbatim without any reference to examples, analogies and illustrations, to mention a few.

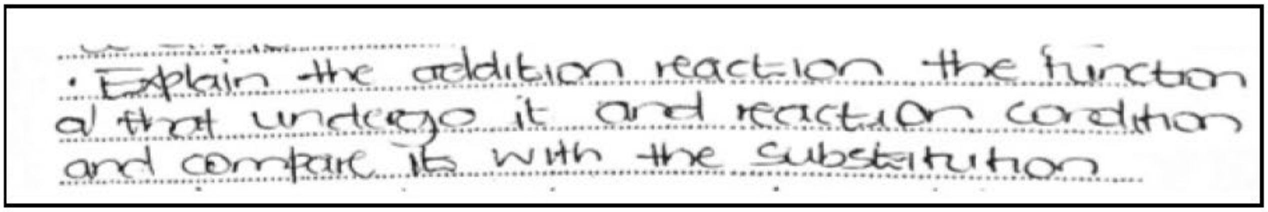

• Explain the addition reaction the function al that undergo it and reaction condition and compare its with the substitution

Figure 9: Extract of representation from Peter's lesson plan

For Mary, the symbols for substances, such as H_2O, in her lesson presentation were included as part of describing how the content will be represented. This indicated the use of only one level of representation, the symbolic level. On the other hand, there was no explicit indication of the specific examples to be used. She only outlined instructions in her lesson plan, indicating that examples would be given.

In a nutshell, Mary had limited knowledge of the different kinds of representation and the corresponding levels of chemistry representation. Figure 10 shows an extract of the pre-lesson study lesson plan on representations for Mary.

Teacher will :
- Assist learners to write previous corrections
- Explain content by doing example in each kind of addition reaction.
- Emphasize condition reactions
  - Hydrogenation – Catalyst is Pt/Ni or Pd
    – alkene dissolved in non-polar solvent
  - Hydration – excess H_2O
    – strong acid (H_2PO_4; HX)
  - Halogenation – add halogen in alkene
    Cl or Br
  - Hydrohalogenation – Add HX in alkene
    – No water
- Give class and home activities

Figure 10: Extract of representation from Mary's lesson plan

On the other hand, Thabo's lesson plan had a symbolic level of representation. He used structural formulae in the equation to show the reaction of but-1-ene and hydrogen bromide that produced 2-bromobutane. Simulations and models relevant to the topic were not used by the teacher (see Figure 11 for the response of Thabo in representations).

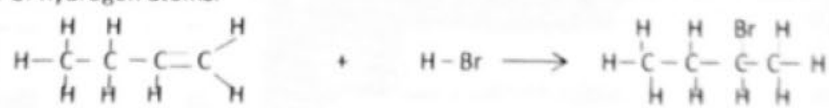
<u>Addition reaction:</u>

- An extra atom is added to a compound
- Addition reaction usually occurs in unsaturated hydrocarbons (alkenes + alkynes)
- Addition reaction is divided into: Hydrogenation, halogenation, hydration and hydrohalogenation

<u>Hydrohalogenation</u>

- Hydrohalogenation is the addition reaction where hydrogen halide (i.e. HCl, HBr, HF and HI)
- During hydrohalogenation, **Markovnikov's rule** is applied which says: When hydrogen halide is added to an unsaturated compound, hydrogen atom attaches itself to a carbon with maximum number of hydrogen atoms.

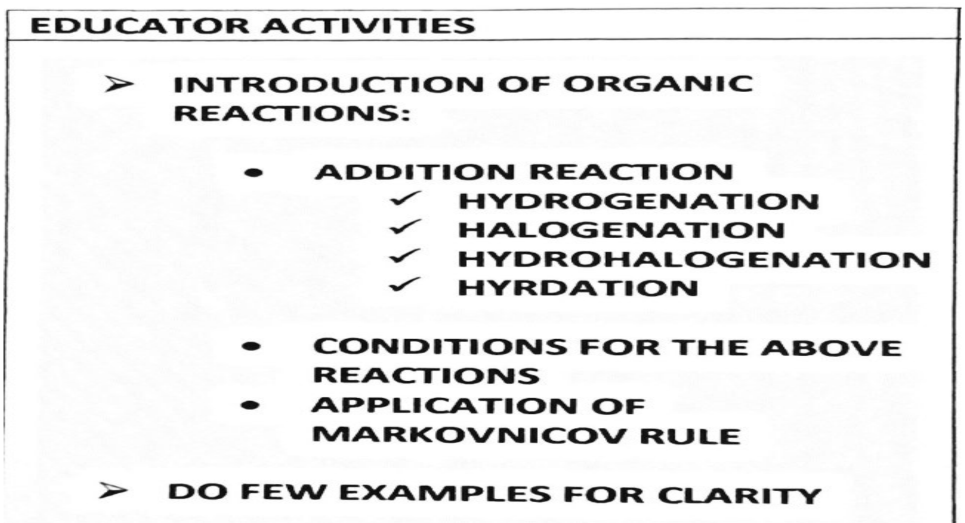
e.g.



But-1-ene + hydrogen bromide → 2-bromobutane

Figure 11: Extract of representation from Thabo's lesson plan

Lastly, Jane's lesson plan does not have levels of representation. There were no clear examples outlined in the lesson plan; no simulations or models that were relevant to the topic. Jane presented the teacher's activities by mentioning the concepts to be taught without considering any of the levels of representation. Jane presented no knowledge of representations in her lesson plan for organic reactions (see Figure 12).


EDUCATOR ACTIVITIES

- INTRODUCTION OF ORGANIC REACTIONS:
  - ADDITION REACTION
    - ✓ HYDROGENATION
    - ✓ HALOGENATION
    - ✓ HYDROHALOGENATION
    - ✓ HYRDATION
  - CONDITIONS FOR THE ABOVE REACTIONS
  - APPLICATION OF MARKOVNICOV RULE
- DO FEW EXAMPLES FOR CLARITY

Figure 12: Extract of representation from Jane's lesson plan

The last component studied was the knowledge of effective conceptual teaching strategies. This is discussed in the next section.

4.2.5 Conceptual teaching strategy

Predominantly, this component comprised all other components of the Topic-Specific PCK construct (Ndlovu & Malcolm, 2022). It is at this component where "teaching procedures" and "ways of ascertaining students' understanding of an idea" are outlined (Rollnick & Mavhunga, 2016, p. 4). Moreover, it is at this component that effective instructional strategies for particular identified misconceptions and representations are considered and directly confronted (Mavhunga & Rollnick, 2013). Table 9 is an extract from the CoRe rubric on conceptual teaching strategies.

Table 9: An extract from the CoRe rubric on conceptual teaching strategies

	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
Teaching strategies	• No evidence of acknowledgement of the students' prior knowledge and misconceptions. • Lacks aspects of curriculum saliency • Use of representations limited to macroscopic or symbolic or scientific symbolic representations.	• Acknowledges students' misconceptions verbally with no corresponding confrontation strategy. • Lacks curricular saliency. • Use of macroscopic and symbolic representations with no linking explanatory notes.	• Considers confirmation and confrontation of students' prior knowledge and/or misconceptions. • Considers at least one aspect related to curricular saliency e.g. sequencing or what not to discuss yet or emphasis on important concepts. • Uses at least two different levels of representations to enforce understanding.	• Consider students' prior knowledge and evidence of confrontation of misconceptions. • Considers at least two aspects related to curricular saliency: sequencing what not to discuss of important conceptual aspects etc. • Use either the macroscopic or symbolic representation with sub-microscopic representation to enforce understanding and may show awareness of learner difficulty

Based on the analysis above under components of TSPCK, Peter wrote students' prior knowledge and representations on his lesson plan. For other components of TSPCK, nothing was found. Peter had limited knowledge of students' prior knowledge because there were no instructional strategies for addressing misconceptions and not even standardised definitions of terms were highlighted. Furthermore, Peter presented the topic by writing the instruction that '*the teacher will explain addition reactions and reaction conditions, and compare them with substitution reactions'*. There were no examples given as part of the teaching strategy. Key terminologies were not defined and the teaching procedures to be followed were not outlined. It was upon this observation that Peter was found to have limited knowledge of conceptual teaching strategy on the topic of addition reactions.

In the case of Mary student's prior knowledge, curricular saliency and representations were presented. Though these components were found, Mary did not write what is difficult to teach. Mary presented pre-concepts from the same grade under students' prior knowledge without explaining to them as follows: '*hydrocarbons, saturated and unsaturated compounds, structural formulas'*. She did not mention misconceptions about this topic. For curricular saliency, she presented a big idea saying; '*unsaturated compounds (alkene) undergo addition reaction*'. She further presented logical key ideas with standardised definitions of terms to be taught. This is what she wrote; '*hydrohalogenation is an addition of HX to an alkene (X=Cl, Br or I). Halogenation is an addition of X_2 to alkenes. Hydration is an addition of H_2O to alkene. Hydrogenation is an addition of H_2 to an alkene'*. Mary used symbols to represent elements, for example, H_2O, but she did not write examples, instead, she wrote instructions that examples would be given. Mary further indicated that emphasis will be on reaction conditions and those reaction conditions were also specified per type of addition reaction. Take note of what she wrote; '*Hydrogenation-catalyst is Pt/Ni or Pd and alkene dissolved in a non-polar solvent. Hydration- excess H_2O and strong acid (H_2PO_4, HX). Halogenation- add halogen in alkene (Cl or Br). Hydrohalogenation- add HX in alkene and no water*'. From the evidence collected from Mary's lesson plan, it was concluded that Mary had limited knowledge of conceptual teaching strategies.

On the other hand, Thabo did not touch on all components of TSPCK. Students' prior knowledge and what is difficult to teach was not written. For curricular saliency, Thabo wrote the objectives of the lesson as follows; '*Learners will be able to identify changes that can be made in saturated and unsaturated hydrocarbons. Learners will be able to identify types of addition reactions. Learners will be able to use structural formulae to balance addition chemical reactions*. Thabo also presented his lesson by explaining addition reactions. This is what he wrote; '*an extra atom is added to a compound. An addition reaction usually occurs in unsaturated hydrocarbons (alkenes and alkyne). The addition reaction is divided into hydrogenation, halogenation, hydration, and hydrohalogenation.*' He further explained one type of addition reaction in more detail; '*Hydrohalogenation is the addition reaction where hydrogen halide (i.e HCl, HBr, HF and HI). During hydrohalogenation, Markovnikov's rule is applied which says: when hydrogen halide is added to an unsaturated compound, a hydrogen atom attaches itself to a carbon with a maximum number of hydrogen atoms*.' Furthermore, Thabo provided examples. He presented a balanced chemical equation using symbols, considering one of the levels of representation. Based on this analysis, Thabo had a limited knowledge of conceptual teaching strategy.

Jane wrote; '*Learners know how to prepare esters'* under students' prior knowledge. Knowledge of *esters* is found in other topics in the same grade. She did not consider misconceptions and errors made by the other students; there were no standardised definitions and knowledge from other grades was not considered. She did not write about what is difficult to teach. She wrote the following under teachers' activities; 'introduction of organic reactions: *addition reaction (hydrogenation, halogenation, hydrohalogenation, and hydration). Conditions for the above reactions. Application of Markovnikov's rule. Do a few examples for clarity.'* Based on what Jane wrote, the knowledge of the big ideas that make up the topic, what teachers intend students to learn from that idea, why it is important for students to know that idea, and what else the teachers might know about that idea that they intend their students not to know yet were not found. A wide range of examples, illustrations, analogies, simulations, and models that are relevant to a topic was not considered, not even levels of representations considered. Based on what Jane wrote, she displayed a limited conceptual teaching strategy.

4.3. Conclusions

As pointed out earlier, this chapter was geared towards responding to the first research question that asked: *What is the quality of teachers' pedagogical content knowledge in planning to teach a section of organic chemistry before the lesson study?* This analysis happened before the planned lesson study that was aimed at developing their knowledge of TSPCK. As shown from the analysis above, overally, three participating teachers showed limited knowledge of students' prior knowledge in planning to teach a section on organic reactions. The participants considered one aspect of students' prior knowledge, meaning the previous knowledge from previously taught concepts regarding students' prior knowledge. None of them indicated awareness of the common misconceptions, common errors, alternative conceptions, and the knowledge that had been learnt from previous grades as part of their knowledge of students' prior knowledge.

These findings are similar to what O'Brien (2017) found where experienced teachers failed to identify students' misconceptions about redox reactions and electrochemistry in a study conducted in a New York context. However, for this component, these findings are in contrast with those of Ndlovu and Malcolm (2022) in stoichiometry with pre-service teachers and Rollnick and Mavhunga (2014) in electrochemistry who found that their participants had a basic knowledge of students' prior knowledge before the intervention that was geared to develop their TSPCK in these topics.

Concerning the component of curricular saliency, this study found that the participating teachers had differing levels of curricular saliency. However, it is worth mentioning that all the participants did not mention why students ought to know a particular big idea, and what they knew at that planning stage that students should not know yet. Mary and Thabo indicated the big idea that 'unsaturated compounds undergo additional reactions'. Rollnick and Mavhunga (2016) revealed that from identifying big ideas, teachers must show awareness of the background concepts needed before teaching the topic and what is most important to understand the topic. All the participating teachers did not indicate such information in their planning stage. Predominantly, the participants indicated basic knowledge of curricular saliency. In electrochemistry, Rollnick and Mavhunga (2014) reported something in contrast with these findings After finding that experienced teachers possessed a developing level of curricular saliency. On the other hand, a study conducted by Aydin-Gunbatar and Akin (2022) on planning to teach acid-base equilibrium revealed that teachers were at a basic level of curricular saliency, similar to these findings.

This study found that the participating teachers did not consider the knowledge of what is difficult to teach when planning to teach organic chemistry. Aydin-Gunbatar et al. (2020) reported that pre-service chemistry teachers were aware of this component of TSPCK as well as alternative conceptions of the chemistry content in pre-tests conducted in PCK for integrated science, technology, engineering and mathematic (STEM) development. On the other hand, Ndlovu (2017) reported that the knowledge of what is difficult to teach in stoichiometry was found at the basic level for the pre-test conducted.

The data collected from the four participants further showed that teachers had limited knowledge of representations. These findings were similar to what Koopman (2017) discovered when investigating how teachers in South Africa engage with all three levels of representation. His findings showed that teachers do not touch on the three levels of representation in their topics. This is also similar to what O'Brien (2017) articulated that levels of representation are challenging because teachers emphasise one domain over others with no connections. For this study, organic reactions were used in data generation to obtain information about how teachers plan to teach organic chemistry. Two participants were able to consider the symbolic level and the other two had no evidence of levels of representation. The nature of the selected topic allowed for all levels of representation but participating teachers were not able to write it in their lesson plans. Therefore, these findings were similar to what Ndlovu (2017) discovered about representation as well as the study conducted by O'Brien (2017) where teachers consider only one level of this representation.

Lastly, from the lesson plans of the participants, teachers' knowledge of conceptual teaching strategy was limited. This is a huge difference from what Rollnick and Mavhunga (2014) discovered in the study of electrochemistry where teachers showed a high proportion of developing and exemplary knowledge. Conceptual teaching strategy required that all components of TSPCK be included in lesson planning as advocated by Ndlovu (2017). Furthermore, Ndlovu (2017) posited that conceptual teaching strategy is the difficult component of TSPCK. Besides, O'Brien (2017) supported this assertion, since conceptual teaching strategy demands the integration of all components of TSPCK. Teaching procedures must be clear, and examples and standardised definitions of terms be included in a lesson presentation. From the evidence collected in this study, two teachers had limited knowledge of conceptual teaching strategies in addition to reactions whilst the other two had basic knowledge. Very few aspects of conceptual teaching strategy were evident from participants.

In conclusion, the overall teachers' knowledge of planned TSPCK was generally found to be limited before the lesson study. This is different from what was found by Zondi (2018) in the study about the quality of TSPCK in planning, where knowledge of planning to teach stoichiometry was exemplary in pre-service teachers. The study conducted by Rollnick and Mavhunga (2014) discovered that teachers showed acceptable content knowledge (CK) but scored below the mean of Rash measures for TSPCK. The next chapter will analyse teachers' planned work after they had been exposed to CoRe-based planning during lesson study.

CHAPTER 5

IMPACT OF LESSON STUDY ON DEVELOPING AND IMPLEMENTING A CONCEPTUAL TEACHING STRATEGY

5.1. Introduction

This chapter focuses on the development of suitable teaching strategies in organic chemistry after the participating teachers had been exposed to CoRe-based planning through lesson study cycles. Hence, the main aim of this chapter is to present findings and respond to the second and third research questions postulated in Chapter 1. *These questions asked: What is a suitable conceptual teaching strategy for teaching a section of organic chemistry?* Secondly, *how do teachers implement the conceptual teaching strategy developed through lesson study to teach a section of teaching grade organic chemistry?*

In response to these research questions, three lesson study cycles were conducted to develop and refine the conceptual teaching strategies to teach the knowledge of organic reaction. Within this topic, the analysis was based on three big ideas. These were: (a) *an ester is a product of an acid-catalyzed condensation between alcohol and carboxylic acid*. (b) *Unsaturated compounds (alkenes) undergo addition reactions*. (c) *Interconversion between haloalkanes and alcohols*

Four participants, including the researcher, were part of a lesson study geared towards developing a suitable conceptual teaching strategy using the CoRe as a planning framework. Before the lesson study, the researcher introduced the construct of TSPCK and CoRe-based planning framework. In this plenary session, the researcher took a lead role whilst the other participants were involved interactively to develop familiarity with the TSPCK construct and the use of CoRe in lesson planning. After the plenary session, the participating teachers collaborated to develop a suitable teaching strategy for teaching organic reactions using all five components of the TSPCK construct.

As discussed earlier, the conceptual teaching strategy is one of the knowledge components of TSPCK, which includes all other components of the construct. In this study, the development of these components together feeds into the development of a conceptual teaching strategy on a topic. In the next section, the development in cycle one is unpacked.

5.2. Developing a Conceptual Teaching Strategy through a Lesson Study

In this section, data collected from the two-lesson study cycle is presented per TSPCK components. The data presentation is structured such that it shows the development from the first CoRe and the improved CoRe as a result of the reflection done in between the lesson study cycles. In each TSPCK component, text in *italics* indicates improvements after reflections. The first component unpacked is students' prior knowledge (SPK).

5.2.1. Planned-Students' Prior Knowledge (pSPK).

From the CoRe (see Appendix A), one prompt is linked to the knowledge of SPK. It foregrounds the consideration of common misconceptions around a big idea of focus. This component asked only one question: *What are typical students' misconceptions when teaching this idea?*

Table 10: Data on students' prior knowledge from the second lesson cycle

	Big idea 1 An ester is a product of an acid-catalysed condensation reaction between an alcohol and a carboxylic acid	**Big idea 2** Unsaturated compounds undergo an addition reaction	**Big idea 3** Interconversion between alcohol and haloalkanes
What are typical students'' misconceptions when teaching this idea?	Learners drink different fruity flavors of fruit juice or sweets thinking it is made out of those fruits but its flavors are made out of esters. Vinegar is used in households but learners are unaware that it is acetic acid.	Learners are familiar with the types of alcohol produced alcohol in the community; learners may tend to compare alcohol produced during hydration reaction with what is produced in their communities. Production of a major product according to Markovnikov's rule can be confused with a minor product. For example, $but-2-ene + hudrogen\ bromide \rightarrow 2-bromobutane$ (major product) $but-2-ene + hydrogen\ bromide \rightarrow$	Learners may confuse hydrolysis reactions with hydration reactions since both reactions produce alcohol. e.g. $haloalkane + strong\ base\ (NaOH) \rightarrow alcohol + hydrogen\ halide.$ (hydrolysis) $haloalkane \frac{UV}{conc.NaOH} \rightarrow alkene + hydrogen\ halide$ (elimination)

		$1 - bromobutane$ (minor product)	

As part of the lesson study, the participating teachers were able to identify SPK across the three big ideas. The big ideas identified were just in the form of statements that are commonly misunderstood. In the second phase, the participating teachers identified more than one misconception per big idea. What was also noticeable is that the teachers could integrate the TSPCK components whilst they identified these misconceptions. For instance, they could use their knowledge of representation (symbolic representation) to explain the nature of the misconception, see Big Ideas 2 and 3 in Table 10.

5.2.2. Planned-Curricular saliency (pCSA)

Secondly, the engagement of the participating teachers in lesson study developed the knowledge of their curricular saliency across the big ideas identified. They further articulated what they wanted their students to know from these Big Ideas. In addition, the knowledge of participating teachers developed by providing examples and standard definitions of terms. Furthermore, the factors that influence the teaching of these ideas were also foregrounded in the lesson development. Table 11 shows what the participants developed under the CoRe prompts that define curricular saliency in their first and second lesson study cycles.

Table 11: Data on curricular saliency from the first and second lesson study cycle

	Big idea 1	**Big idea 2**	**Big idea 3**
What do you intend students to learn from this idea?	The ester is formed during a reaction called esterification. Esterification is a reaction of alcohol and carboxylic acid in the presence of sulfuric acid as a catalyst. *e.g.* $alcohol + carboxylic\ acid \frac{H_2\,SO_4}{\Delta H} \rightarrow ester + water$ ***Reaction conditions:*** *Add a few drops of $H_2\,SO_4$.*	Halogenation, hydrogenation, hydration, and hydrohalogenation are examples of addition reactions. ***Hydrohalogenation*** – *addition of hydrogen halide e.g. HCl, HBr, or HI to an alkene. No water must be present. Major products formed during this reaction. Haloalkane must be*	Reactions of hydrogen halide (HCl/ HBr) with alcohols produce haloalkane and water. Reactions of bases with haloalkanes during hydrolysis reaction produce alcohol and hydrogen halide. *Hydrolysis is a reaction of salt with water*

	Heat in a water bath.	*dissolved in a non-polar solvent.* ***Halogenation*** *– addition of halogen e.g.* Cl_2 *or* Br_2 *to alkene.* ***Hydration*** *– addition of excess* H_2O *in alkene and a small amount of dilute strong acid (e.g.*H_3PO_4*, or* H_2SO_4 *). A major product is formed during this reaction.* ***Hydrogenation****- the addition reaction of hydrogen to an alkene.* *Reaction condition: alkene is dissolved in a non-polar solvent with a catalyst (Pt/Pd/Ni) in an* H_2 *atmosphere.*	*The reaction between alkane and halide produces haloalkane and hydrogen halide.*
Why is it important for students to know this idea?	Esters are essential in the food industry because they have fruity smells. *Ester is also used in medicine to produce flavours in syrups and in the cosmetic industry to produce a fruity smell in lotions.*	Addition reactions are helpful in the industry to produce polyethylene for the production of plastics. Polypropylene is used for packaging. Polyvinyl chloride for construction and plastic piping. *The hydrogenation reaction is also used in the preparation of margarine (a concept done in grade 9 natural sciences).*	Hydrogen halide is a valuable intermediate for the manufacture of other substances. *e.g. hydrogen halide reacts with alcohols to produce haloalkane*
What else do you know about this idea that you intend students not to know yet?	The reaction of esters to form polyester.	Addition reaction of polymers.	The condensation reaction of polymers *The reaction is regarded as hydrolysis even though hydrolysis is the sub-reaction*

What other factors influence the teaching of this idea?	Learners associate alcohol with the ones found in taverns, for example, beer. *The knowledge of acids and bases in grade 11, especially the acid-base theories.* *The learners know the structural formula for a functional group of alcohol and carboxylic acids from knowledge of homologous series.*	Definition of hydration and hydrolysis reaction because both reactions involve the presence of –OH. *The knowledge of homologous series, especially alkane. Knowledge of hydrogenation in grade 9 natural sciences for (margarine only) unsaturated fats.*	Learners might confuse hydrolysis and hydration reactions. *The knowledge of saturated organic compounds.*

As part of participating in the lesson study, the participating teachers developed knowledge of CSA. The participating teachers could provide a sequence of these three Big Ideas identified. Knowledge of each Big Idea informs the other Big Ideas in a certain order. The pre-concepts relevant to organic reactions were identified. The conceptual scaffolding of representations and students' prior knowledge was evident. This was evidence of factors influencing the teaching of ideas. For example: '*Halogenation – addition of halogen e.g.* Cl_2 *or* Br_2 *to alkene'*... (Symbolic representation), and *'the knowledge of homologous series, especially alkane. Knowledge of hydrogenation in grade 9 natural sciences for (margarine only) unsaturated fats'*... (Students' prior knowledge). This is the evidence of REP and SPK mentioned under CSA, and this shows the integration of TSPCK components. The next component presented is the knowledge of what is difficult to teach.

5.2.3. Planned-What is difficult to teach (pWDT)

The third component linked to TSPCK is the consideration of what is difficult to teach. The knowledge of participating teachers identifying specific concepts with reasons linking to specific gatekeeping concepts and TSPCK components was developed, for example, students' prior knowledge and aspects of curricular saliency. Misconceptions were identified across three Big Ideas identified. There were new developments made in the second lesson study on what is easy/difficult to teach. Table 12 presents the teacher's knowledge of what is easy/difficult to teach on the first and second lesson study cycles.

Table 12: Data on what you consider easy/difficult about teaching Big Ideas

	Big idea 1	**Big idea 2**	**Big idea 3**
What do you consider easy or difficult about teaching this idea?	Misconceptions during IUPAC naming and structural formulae of alcohols and carboxylic acids can lead to an incorrect ester. *It is difficult to explain that hydroxyl group (OH) is from a carboxylic and a bond with hydrogen atom (–H) is from an alcohol during esterification. Teachers need to use different colours when presenting this and further demonstrate it using models.*	Addition reactions involve many types of reactions with related reaction conditions which bring a lot of confusion to learners during lesson presentations, for example, in hydrohalogenation condition: no water must be present; the presence of water can produce alcohol. *Water contains stronger intermolecular forces than hydrogen halide*	In the case where one reactant is provided, learners may confuse substitution with elimination reactions. *The reaction condition of a dilute strong base during hydrolysis confuses learners with a concentrated strong base for dehydration reaction. Hydrolysis uses ethanol dissolved in water but dehydration uses pure ethanol. E.g.* $alkane \frac{NaOH}{dil} \rightarrow alcohol + inorganic\ compound$ *Learners may assume that for substitution reactions, there are two reactants and two products.* *Learners may confuse reaction conditions since there is also a possibility of elimination reaction if a strong concentrated base is used. E.g.* $alkane\ \frac{NaOH}{conc} \rightarrow alkene + H_2$

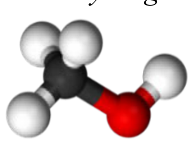
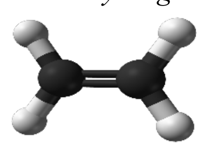
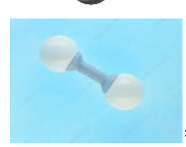
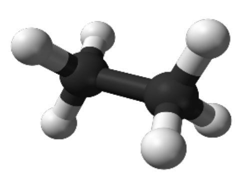
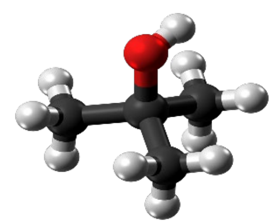
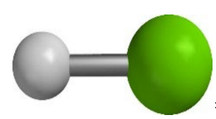
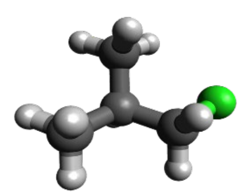
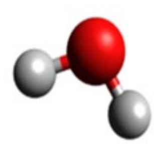
Based on data presented in Table 5.6, it is evident that participating teachers' knowledge of what is difficult to teach was developed from cycles 1 to 2. Participating teachers articulated specific concepts with reasons, linking to gatekeeping concepts. For example: *it is difficult to explain that hydroxyl group (OH) is from a carboxylic and a bond with hydrogen atom (–H) is from an alcohol during esterification. Teachers need to use different colours when presenting this and further demonstrate it using models.* They further drew from the knowledge of SPK and CSA to unpack difficult concepts. For example, *the reaction condition of a dilute strong base during hydrolysis confuses learners with a concentrated strong base for dehydration reaction. Hydrolysis uses ethanol dissolved in water but dehydration uses pure ethanol. E.g.* $alkane \frac{NaOH}{dil} \rightarrow alcohol + inorganic\ compound$

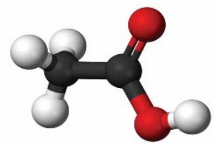
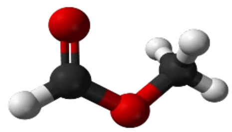
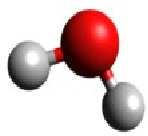
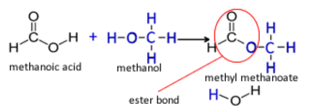
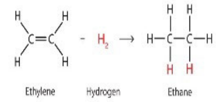
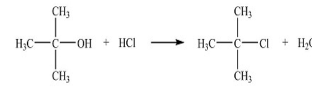
(hydrolysis) and. $alkane \xrightarrow[conc]{NaOH} alkene + H_2$ *(dehydration).* The fourth component of TSPCK to be unpacked on the next subtopic is the knowledge representations.

5.2.4. Planned-Representations (pREP)

Participating teachers' knowledge of representations was developed during lesson development in the first and second lesson study cycles. They considered three levels of representations in all three Big Ideas. Table 13 presents lesson planning under knowledge of representations.

Table 13: Data on representations

	Big idea 1	**Big idea 2**	**Big idea 3**
What representations would you use in your teaching strategy?	Symbolic representations can be used to write balanced equations for esterification. Models can be used for microscopic representation. The experiment can be done to represent the macroscopic level. Learners can smell the fruity smell of esters. *e.g. Ball and stick Models will be used for microscopic representation. To demonstrate the formation of ester, a simple experiment must be conducted to represent the process macroscopically.* ***<u>Ball and stick model</u>*** *Clue for balls:* *Black- carbon* *Red- oxygen* *White-hydrogen*  +	Models or sweets (allsorts/marshmallows with toothpicks) can be used to represent the microscopic level of atoms. Symbols can be used to represent equations for different addition reactions. ***<u>Ball and stick model</u>*** *Clue for balls:* *Black- carbon* *Red- oxygen* *White- hydrogen*  +  =  ***<u>Structural formulae:</u>***	Symbolic representations will be used. E.g. HCl/HBr, $C(CH_3)_3OH$ Ball and stick Models can also be used to represent the microscopic level. ***<u>Ball and stick model</u>*** *Clue for balls:* *Black- carbon* *Red- oxygen* *White- hydrogen*  +  =  +  ***<u>Structural formulae:</u>***

	 $=$  $+$  ***Structural formulae:***  ***IUPAC names:*** $methanol + methanoic\ acid \rightarrow methyl\ methanoate + water$ ***Condensed structural formulae:*** $CH_3OH + HCOOH \rightarrow CH_3OOCH + H_2O$	 ***IUPAC names:*** $ethene + hydrogen = ethane$ ***Condensed structural formulae:*** $CH_2CH_2 + H_2 \rightarrow CH_3CH_3$	 ***IUPAC names:*** $2-methylpropan-2-ol + hydrogen\ chloride = 2-chloro-2-methylpropane + water$ ***Condensed structural formulae:*** $C(CH_3)_3OH + HCl \rightarrow C(CH_3)_3Cl + H_2O$

The knowledge for representations was developed for participating teachers across the three big ideas. Participating teachers considered the macroscopic level of representation by mentioning that experiments will be used during lesson presentations to enforce knowledge of organic reactions to learners. That will enable learners to build knowledge of organic reactions using their senses. In addition, participating teachers foregrounded symbolic representations during the lesson development stage. Furthermore, participating teachers considered the sup-microscopic level of representation when using the stick-and-ball model when representing equations. The knowledge of participating teachers was also developed by integrating these three levels of representation. The last component of TSPCK is the conceptual teaching strategy, which is presented below.

5.2.5. Planned-Conceptual teaching strategy (pCTS)

Conceptual teaching strategy is the last component of TSPCK which integrates all other components as it was mentioned earlier in this chapter. Based on the data presented under students' prior knowledge, curricular saliency, what is difficult to teach, and representations, it is apparent that the knowledge of participating teachers was developed during the lesson study. For example, they identified students' misconceptions associated with big ideas as shown in the excerpt below:

> *Learners drink different fruity flavors of fruit juice or sweets thinking it is made out of those fruits but its flavors are made out of esters.*
>
> *Production of a major product according to Markovnikov's rule can be confused with a minor product. For example,*
>
> $but-2-ene+hudrogen\ bromide\ \rightarrow 2-bromobutane$ *(major product)*
>
> $bu-2-ene+hydrogen\ bromide\ \rightarrow 1-bromobutane$ *(Minor product)*

Furthermore, the knowledge of participating teachers was developed under the knowledge of curricular saliency. Participants stated what they intended their students to know from each Big Idea. For example, in esterification:

> *The ester is formed during a reaction called esterification. Esterification is a reaction of alcohol and carboxylic acid in the presence of sulfuric acid as a catalyst. e.g.* $alcohol+carboxylic\ acid \xrightarrow[\Delta H]{H_2\,SO_4} ester+water$

Participants stated the importance of teaching each big idea. Regarding the addition reaction, they pointed that:

> *Addition reactions are helpful in the industry to produce polyethylene for the production of plastics.*

Moreover, participants developed the knowledge of pinpointing the knowledge they have which is not required to be presented to students yet. For example:

> *The condensation reaction of polymers. The reaction is regarded as hydrolysis even though hydrolysis is the sub-reaction*

Furthermore, the knowledge of identifying factors that influence Big Ideas was developed. For example:

> *The knowledge of acids and bases in grade 11, especially the acid-base theories.*

The learners know the structural formula for a functional group of alcohol and carboxylic acids from knowledge of homologous series.

Participating teachers developed the knowledge of what is difficult when teaching these Big Ideas. For example:

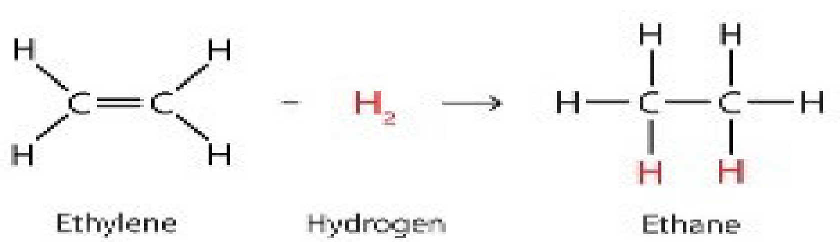
The reaction condition of a dilute strong base during hydrolysis confuses learners with a concentrated strong base for dehydration reaction. Hydrolysis uses ethanol dissolved in water but dehydration uses pure ethanol. E.g. $alkane\frac{NaOH}{dil} \rightarrow alcohol + \ inorganic\ compound$ *Learners may assume that for substitution reactions, there are two reactants and two products.*
Learners may confuse reaction conditions since there is also a possibility of elimination reaction if a strong concentrated base is used. E.g. $alkane\ \frac{NaOH}{conc} \rightarrow alkene + \ H_2$

The engagement of participating teachers developed their knowledge of representations. For example, they presented ball-and-stick models (particulate representations) and structural formulae (symbolic representation).

Ball and stick model

Clue for balls: A black ball represents a carbon atom and a white ball represents a hydrogen atom

Structural formulae:



IUPAC names:

$$ethene + hydrogen = ethane$$

Condensed structural formulae:

$$CH_2CH_2 \ + \ H_2 \rightarrow \ CH_3CH_3$$

In addition to the considerations above, Table 14 presents the effective teaching strategies the participants planned during lesson study cycles.

Table 14: Effective teaching strategies in esterification

<table>
<tr><td></td><td>Big Idea 1</td></tr>
<tr><td>What effective teaching strategies would you use to teach this big idea?</td><td>

Demonstration:

- The teacher can demonstrate the formation of esters using for example ethanol and ethanoic acid. Learners can identify the characteristic smell.
- Using the above example, a balanced chemical reaction can be represented in IUPAC names, condensed structural formula, and structural formula.

or example $ethanol + ethanoic\ acid\ \rightarrow ethyl\ ethanoate + water$

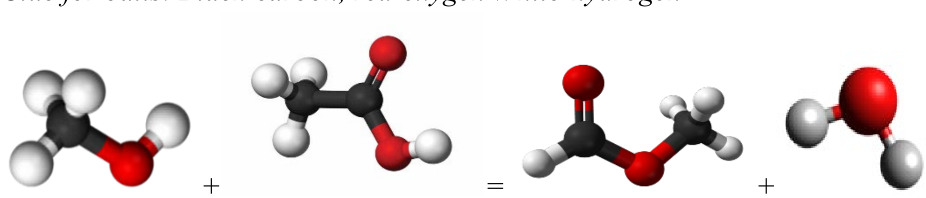
$$CH_3CH_2OH + CH_3COOH\ \ CH_3CH_2OCOCH_3 + H_2O$$

Use of models:

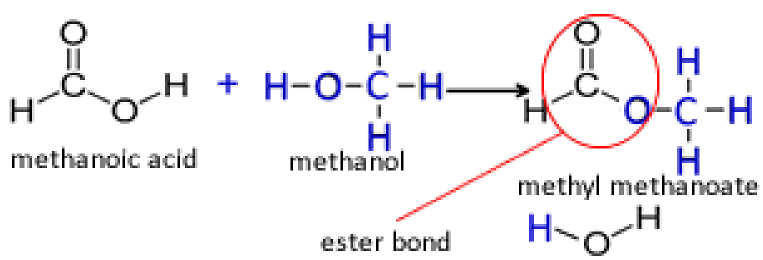
Learners can be given models to build compounds and re-arrange them to form products.

<u>Ball and stick model</u>

Clue for balls: Black-carbon, red-oxygen White-hydrogen



<u>Structural formulae:</u>



<u>IUPAC names:</u>

$$methanol + methanoc\ acid\ \rightarrow methyl\ methanoate + water$$

<u>Condensed structural formulae:</u>

$$CH_3OH +\ HCOOH\ \rightarrow\ CH_3OOCH +\ H_2O$$

</td></tr>
<tr><td>What questions would you consider important to ask in your teaching strategy?</td><td>

- Teachers can probe questions on the importance of esters in industry.
- Teachers can use the IUPAC name for reactions of alcohols and carboxylic acids and allow learners to give products and then present balanced chemical equations using a structural formula, condensed structural formula, or molecular formula.

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

	• The teacher can probe questions on reaction conditions for esterification.

Table 15: Effective teaching strategies in addition reactions

<table>
<tr><td></td><td>Big Idea 2</td></tr>
<tr><td>What effective teaching strategies would you use to teach this big idea?</td><td>

Demonstration:

- Models can be given to learners to build compounds and re-arrange them to form a product.

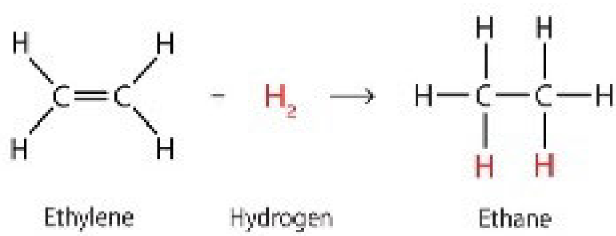
Hydrogenation- the addition reaction of hydrogen to an alkene.
Reaction condition: alkene is dissolved in a non-polar solvent with a catalyst

<u>Ball and stick model</u>

Clue for balls: A black ball represents a carbon atom and, a white ball represents a hydrogen atom

Analogies:
Usage of symbols to draw structural formulas for addition reactions.

<u>Structural formulae:</u>



<u>IUPAC names:</u>

$$ethene + hydrogen = ethane$$

<u>Condensed structural formulae:</u>

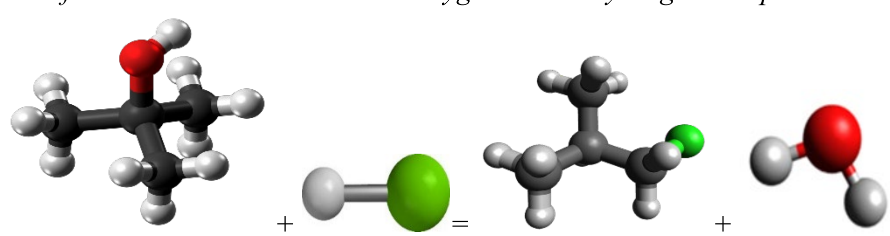
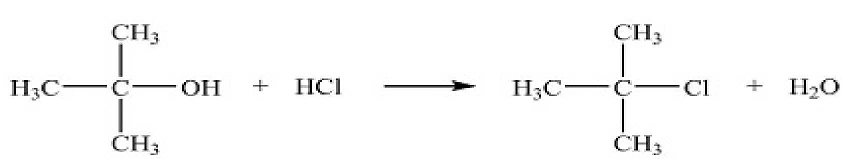
$$CH_2CH_2 + H_2 \rightarrow CH_3CH_3$$

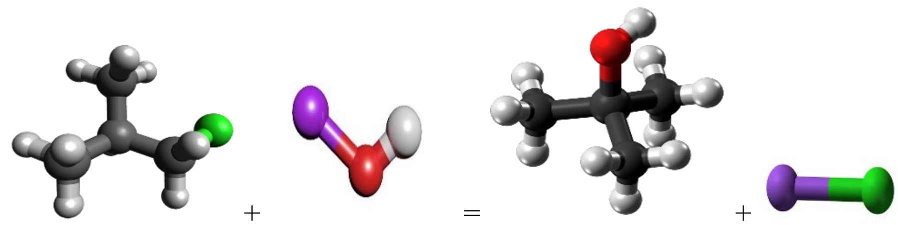
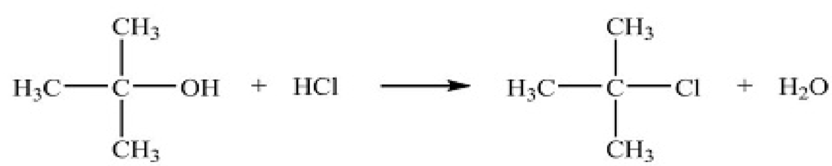
Reaction conditions: Add Pt/Ni/Pd as a catalyst
Hydrohalogenation – addition of hydrogen halide e.g. *HCl, HBr,* or *HI* to an alkene. No water must be present. Major products are formed during this reaction. Haloalkane must be dissolved in a non-polar solvent.
Halogenation – addition of halogen e.g. Cl_2 or Br_2 to alkene.
Hydration – addition of excess H_2O in alkene and a small amount of dilute strong acid (e.g. H_3P, or H_2SO_4). A major product is formed during this reaction.
(Pt/Pd/Ni) in an H_2 atmosphere.

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

What questions would you consider important to ask in your teaching strategy?	Teachers can use the IUPAC name for halogenation, hydration, hydrogenation, or hydrohalogenation, and allow learners to write products and then present balanced chemical equations using a structural formula, condensed structural formula, or molecular formula. Teachers use flow diagrams and allow learners to predict types of addition reactions and write major or minor products that can be produced. The teacher can probe questions on reaction conditions for types of addition reactions.

Table 16: Effective teaching strategies in substitutions

	Big idea 5 **Interconversion between alcohols and haloalkanes**
What effective teaching strategies would you use to teach this big idea?	**Probing questions:** Give examples of saturated organic compounds. What is meant by hydration reaction? **Analogies:** Substitution reaction occurs when saturated molecules react with other substances to produce saturated molecules. Examples of saturated molecules are alkanes, alcohols, and haloalkanes. The focus is on the Interconversion between haloalkanes and alcohol. **Examples: 1. Reaction of alkanes with halogens to produce haloalkane and hydrogen halide** propane + bromine = 2-bromopropane **$CH_3CH_2CH_3$ +Br_2 = $CH_3CHBrCH_3$ + HBr** **Reaction condition**: sunlight/ultraviolet light/heat and add halogen **2. Reaction of alcohol with hydrogen halide to produce haloalkane and water** ***<u>Ball and stick model</u>*** *Clue for balls: Black- carbon Red- oxygen White- hydrogen. Purple-sodium*  ***<u>Structural formulae:</u>***  ***<u>IUPAC names:</u>***

	$2 - methylpropan - 2 - ol + hydrogen\ chloride$ $= 2 - chloro - 2 - methylpropane + water$ ***<u>Condensed structural formulae:</u>*** $C(CH_3)_3OH + HCl \rightarrow C(CH_3)_3Cl + H_2O$ **Reaction condition:** Tertiary alcohols work best in this reaction. Primary and secondary alcohols react very slowly and at high temperatures. **3**. The reaction of haloalkanes with bases to form alcohols and salts is called hydrolysis  ***<u>Structural formulae:</u>***  ***<u>IUPAC names:</u>*** $2 - methylpropan - 2 - ol + hydrogen\ chloride$ $= 2 - chloro - 2 - methylpropane + water$ ***<u>Condensed structural formulae:</u>*** $C(CH_3)_3OH + HCl \rightarrow C(CH_3)_3Cl + H_2O$ **Reaction conditions:** Add a strong base (NaOH/KOH) and heat
What questions would you consider important to ask in your teaching strategy?	• In a given haloalkane/alcohol, students can be asked to write a major product or minor product that can be produced during the substitution reaction. • In a given substitution reaction, students can be asked to write down reaction conditions for that reaction. • In a given substitution reaction, students can be asked to use a structural formula to write down a balanced reaction

Based on the data presentment, it is seen that participating teachers developed knowledge of conceptual teaching strategies in planning to teach organic chemistry during the lesson study approach. The next topic is on implementation of a conceptual teaching strategy.

5.3. Evaluating the Enacted-TSPCK.

This sub-section presents the implementation of the first and second conceptual teaching strategies developed from the lesson study. The main purpose of unpacking these two lessons was to respond to the third research question on: *how do teachers implement the conceptual teaching strategy developed through lesson study in teaching grade 12 organic chemistry*? Participants enacted the collectively planned TSPCK whilst the researcher observed and recorded.

To analyse these observed lessons, the enacted TSPCK rubric (see Appendix C) taken from Mapulanga et al. (2023) was used. Table 17 shows an extract of this rubric for the first CoRe aspects of enacted learner prior knowledge.

Table 17: Data on what you consider easy/difficult about teaching Big Ideas

Prompt	Level of TSPCK enactment				
	Very limited (0)	**Limited (1)**	**Basic (2)**	**Developing (3)**	**Exemplary (4)**
1	• Not answered	• No identification of misconceptions/alternative conception (stated answer does not represent a misconception)	• Identifies at least one misconception/alternative conception but does not provide a standardized definition or reason for it	• Identifies two misconceptions/alternative conceptions and provides a standardized definition or reason for one or both	• Identifies three or more misconceptions/alternative conceptions and provides a standardized definition or reason for them

As with all the other enacted-TSPCK components, the same rubric in Appendix C was used to score the observed lesson. Table 5.9 shows how the two signature lessons from cycle 1 and cycle 2 were compared. The numerical values were used for qualitative aspects of enacted CoRe. The rubric reflects the ordinal scores describing the developing quality of enacted-TSPCK from 'very limited' to 'exemplary' component interaction. As mentioned earlier in Chapter 4, the average scores are not understood to represent the quality of TSPCK through mathematically mixing/integrating the components but they are a proxy of the overall quality observed from collective lesson enactment by the participants.

Because of the scope of this work, only one big idea was followed during CTS implementation and observation, that is, "*an ester is a product of an acid-catalyzed condensation reaction between an* *alcohol and a carboxylic acid"*. Table 18 shows that the participating teachers developed their enacted TSPCK regarding this big idea. In the same way, on component average, each TSPCK component knowledge was developed. It is worth noting as postulated by Mavhunga (2017) that the TSPCK scores presented in Table 18 were not analysed to make any statistical inferences or claims. They were useful in getting the proxy of the quality of enacted-TSPCK by participants across the components and in totality.

Table 18: Signature lessons from Cycle 1 and Cycle 2 on Esterification

The aspect of CoRe enacted	First lesson presentation after first LS	The second lesson presentation after the second LS
Enacted-student prior knowledge (eSPK)		
1. What are typical learners' misconceptions when teaching/learning this idea?	0	3
2. What concepts need to be taught before teaching this idea?	3	4
The average score for eSPK	***2***	***4***
Enacted-curricular saliency (eCSA)		
3. What do you intend the learners to know about this idea?	2	4
4. Why is it important for students to know this?	3	4
5. What else do you know about this idea (that you do not intend learners to know yet)?	0	4
Average score for eCSA	***2***	***4***
Enacted-what is difficult to teach (eWDT)		
6. What do you consider difficult about teaching this idea?	2	3
The average score for eWDT	***2***	***3***
Enacted-representations (eREP)		
7. What representations (teaching aids, diagrams, equations, models, etc.) will you use in your teaching strategies?	2	3
8. How will the representations help learners' understanding of the idea?	3	3
The average score for eREP	***2***	***3***
Enacted-conceptual teaching strategies (eCTS)		
9. What effective teaching strategies will you use to teach this idea?	2	3
10. How will the strategies help students understand the concept or idea?	2	3
The average score on eCTS	***2***	***3***

In the next sections, the scores on enacted TSPCK in Table 18 are unpacked.

5.4. Unpacking the enacted TSPCK in the Lessons

In the second phase of the first cycle, one teacher presented the first CoRe-based lesson in the classroom whilst the researcher was observing and recording. The analysis of enacted CoRe was grouped according to components of TSPCK. The first component analysed was students' prior knowledge.

5.4.1. Enacted-Students' prior knowledge (eSPK)

The knowledge provided by the presenting teacher (PT) showed that enacted TSPCK was at the basic level. All the concepts identified were pre-requisite to this idea. Nothing was mentioned about students' misconceptions. For example, PT said:

> PT: "*How can you see that this is an acid? The presence of a carboxyl group. Anyone who can write equations for the structural formulae, condensed, and molecular formulae? H_2SO_4 is a catalyst.*"

The questions posed by PT indicated basic TSPCK since he could identify the pre-requisite concepts to be taught before this big idea. After the second cycle, there was development on enacted TSPCK after the discussions of the first lesson enacted. The teacher identified prerequisite concepts to be taught before this idea. In addition, there was an attempt to attend to students' misconceptions and provide a standardised definition of terms within this TSPCK component. For example, the teacher said:

> *PT: "Ester is a homologous series formed from two homologous series, alcohol and carboxylic acids. How do I identify that this is an alcohol and this is a carboxylic acid? How do I identify that this is alcohol? Ok, when carbon is bonded to –OH, that is an alcohol, and if oxygen is bonded to the carbon which is bonded to –OH is a carboxylic acid. Who can give me an example of alcohol? Pentanol? You can't tell whether it's a primary or secondary alcohol. The IUPAC name is pentan-1-ol. Which class of alcohols do we use? Primary, secondary, or tertiary? We use primary alcohol. Why do we use primary alcohol? They have larger surface area"*

Based on the analysis of enacted TSPCK within this component, it could be inferred that there was a significant improvement from basic to exemplary. The next component that was analysed is the knowledge of enacted CSA.

5.4.2 Enacted-curricular saliency (e-CSA)

Similarly, these components in the first cycle were found to be basic. The PT highlighted concepts that represent the content that needs to be learnt in this idea. In addition, reasons were highlighted the importance of the topic with reference to conceptual considerations. However, there was no integration with other TSPCK components. The PT did not respond to the prompt on the knowledge of what he intended not to teach his learners. The extract below shows what the presenting teacher said

> PT: *"Heat in water bath not directly in flame. Why? Alcohols are highly flammable. What else can be added? Add concentrated sulphuric acid as a catalyst. What other product is produced except ester? Water. What are the characteristics or properties of esters? They have a characteristic smell. It is important that you know that esters have a pleasant smell. For example, smell of a banana. Esters are used in the food industry, e.g., to manufacture juice. Esters are used in the cosmetic industry, e.g., to manufacture soaps"*

In the second lesson, the PT showed improved knowledge of enacted TSPCK as he identifed concepts that indicated science content to be learnt. In addition, he also provided reasons for the importance of the topic, including a reference to conceptual consideration. Furthermore, the PT showed evidence of integrating another TSPCK component, that is, SPK in eCSA. Lastly, the identified concepts were within the grade level and relevant for the current level of learners. Below is an extract indicating exemplary enacted TSPCK in this component.

> PT: "*You need to know how the ester is being formed. Ester is formed from two homologous series. Yes, the ester is also a homologous series but it is formed from other two homologous series. One of them is an alcohol and another one is a carboxylic acid. What are we worried about, is the conditions. When you write a reaction, you also need to write conditions. Conditions are concentrated sulphuric acid and heat. What is the function of H_2SO_4? It is a dehydrating agent. What else? It acts as a catalyst. What is the function of a dehydrating agent? "To remove water from a substance. Alcohols and carboxylic acids are mixed and form two products. What are those two products? One of them is water because H_2SO_4 removes water. Therefore, ester is*

one of the products. Who can give me an example of alcohol? Which class of alcohols do we use? Primary, secondary, or tertiary? We use primary alcohols"

The next analysed component of enacted TSPCK is knowledge of what is difficult to teach.

5.4.3 Enacted-what is difficult to teach (eWDT)

The enacted TSPCK was developed from basic to developing TSPCK. The extract below shows that the PT provided specific concepts thus leading to learner difficulty although there was no reason given related to other TSPCK components.

PT: "Reaction conditions for this reaction are mild heat and H_2SO_4 as a catalyst. This reaction uses a primary alcohol.

However, in the second lesson, the PT drew from LPK to highlight what is difficult to teach:

PT: "Reaction conditions are concentrated H_2SO_4 as a dehydrating agent (to remove water) and heat. Do not specify whether mild heat, write heat only. When you write an equation include reaction conditions. Use primary alcohols because they have a larger surface area.

The next component focuses on enacted-representations.

5.3.4 Enacted-Representations (eREP)

The knowledge of enacted TSPCK was developed from basic to developing level in this component. PT used equations and symbols when demonstrating the formation of an ester and these equations talk to each other. The examples given to learners were very limited though the explanation of the formation of alkyl ethanoate was explicit. Figure 13 shows representations of where he was using both word and symbol equations to demonstrate formations of esters in the first lesson.

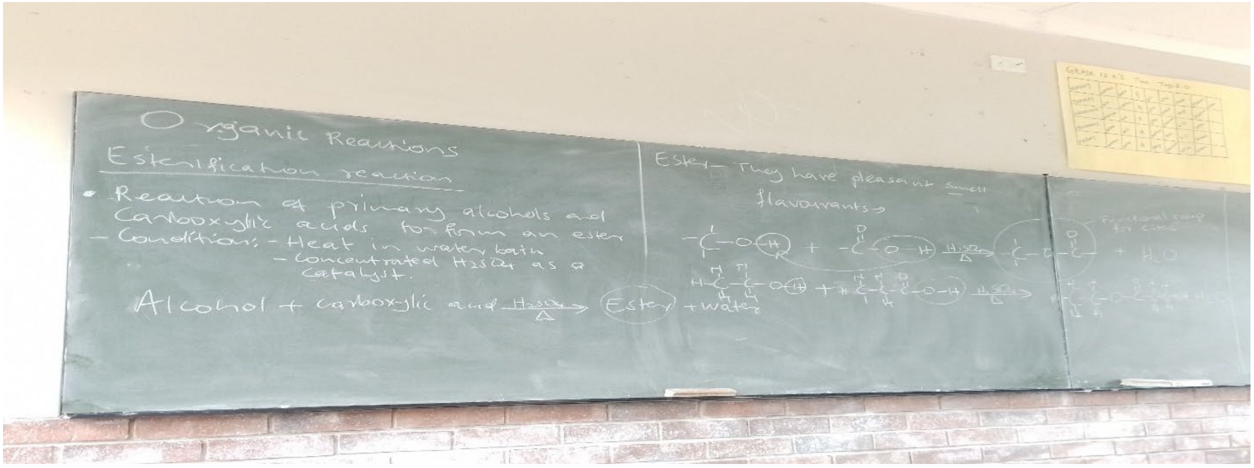


Figure 13: Representation of esterification at a symbolic level

On the other hand, enacted TSPCK in the second lesson scored a developing level of enacted REP. PT probed questions to learners after making a model for learners to identify the homologous series and IUPAC name for a demonstrated ball-and-stick model. He gave a clue for colours:

> PT: *"Black is for a carbon atom, white is for the hydrogen atom, and red is for an oxygen atom. The grey stick is for single bond and the white stick is for double bond."* This representation was at a sub-microscopic level.

Furthermore, PT used symbols when presenting formulae on the chalkboard. Figure 14 is the presentation of the symbolic level.

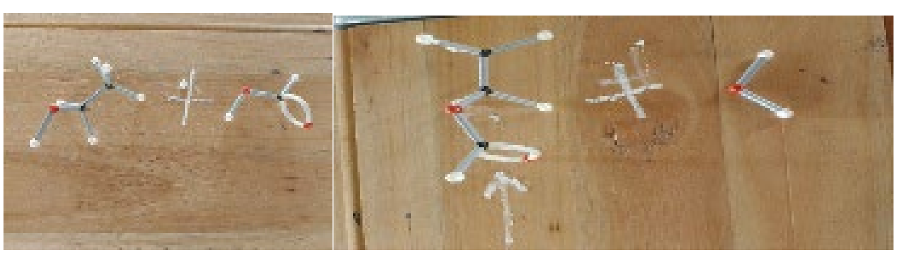


Figure 14: Presentation on esterification at the sub-microscopic level

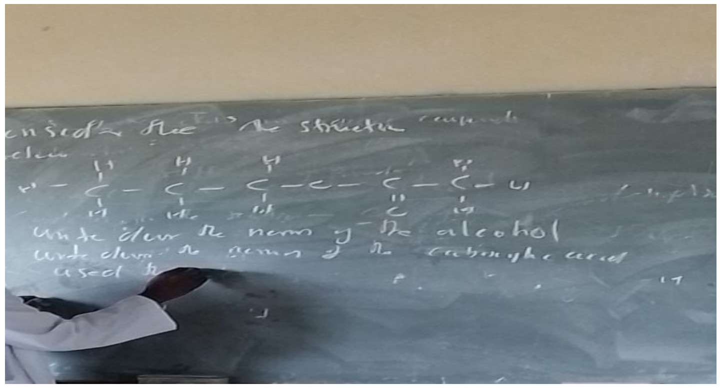


Figure 15: Presentation of symbolic level

The evidence analysed in the next lesson showed that knowledge of eREP was developing. PT integrated two levels of representation. These representations were relevant to the concept enacted. There was a linkage in concepts presented and the levels of representation used, but there was no evidence of integration to other components of TSPCK. The next component of enacted TSPCK to analyse is the conceptual teaching strategy.

5.3.5 Enacted-Conceptual teaching strategy (eCTS)

Based on the evidence from the lesson presentation of the other four components of TSPCK, the knowledge of PT in the first enacted TSPCK was found at a basic level which was improved in the second lesson to a developing level. PT in the first lesson was able to identify teaching strategies with clear descriptions of how they will be used. Furthermore, PT considers concepts to be learnt and linkage was clear with his teaching strategy, but he failed to attend to learners' misconceptions since he considered symbolic representation only. Moreover, the linkage of other TSPCK components during lesson enactment was poor. Based on this assertion, enacted CTS for the first lesson presented was found to be basic. This was also confirmed by the average scores of the other four TSPCK components in Table 5.11.

On the other hand, the knowledge of enacted TSPCK on conceptual teaching strategy for the second lesson was found to be developing. PT identified the teaching strategies with explicit descriptions of how they will be used with aspects related to curricular saliency. Moreover, there were links between strategies and concepts learnt. PT further attended to learners' misconceptions though he did not represent those misconceptions using structural formulae. For instance, "*Pentanol? You can't tell whether it's a primary or secondary alcohol. The IUPAC name is pentan-1-ol"*. This can be further represented by drawing a structural formula to show the position of a hydroxyl group in a carbon chain. Based on this evidence, knowledge of enacted TSPCK in conceptual teaching strategy was found developing. This was also confirmed by the average scores of other components of TSPCK in Table 19. These scores were used for qualitative description only, not for statistical analysis.

Table 19: Average scores of enacted TSPCK components

Component	Average score of first lesson	Average score of second lesson
Average score of eSPK	2 (basic)	4 (exemplary)
Average score of eCSA	2 (basic)	4 (exemplary)
Average score of eWDT	2 (basic)	3 (developing)
Average score of eREP	2 (basic)	3 (developing)
Average score of eCTS	**2 (basic)**	**3 (developing)**

5.4. Conclusion

This section will theoretically confirm existing views, refutations, extensions, and differencing aspects of the findings of this study with existing literature. This will be done in two folds: looking at teachers' planned knowledge (developed conceptual teaching strategy) after the intervention (lesson study) and the teacher's knowledge of lesson enactment (implementing planned conceptual teaching strategy). The main purpose of this chapter was to respond to two research questions. The questions asked are: *What is a suitable conceptual teaching strategy for teaching a section of organic chemistry*? *How do teachers implement the conceptual teaching strategy developed through the lesson study in teaching grade 12 organic chemistry*?

The findings revealed that that was a significant development in each component of planned TSPCK during the first and second lesson study cycles across three big idea identified. This study confirmed the findings by Mapulanga et al. (2023) where teachers planned knowledge was improved in respiration. On the other hand, the findings showed that teachers' knowledge of enacted TSPCK was developed the through lesson study from basic to a developing level.

Knowledge of eSPK was developed from a basic level to an exemplary level. The knowledge of eCSA was developed from basic to exemplary as well. Also, the knowledge of eWDT was developed from basic to a developing level. Furthermore, the knowledge of eREP was developed from a basic level to a developing level. Lastly, the knowledge of enacted eCTS was developed from basic to developing levels. This confirms that conceptual teaching strategy can be developed through the engagement of teachers in a professional platform, a lesson study approach.

CHAPTER 6

FURTHER DISCUSSIONS, RECOMMENDATIONS AND CONCLUSIONS.

6.1 Introduction

The main purpose of this chapter is to pull it all together by highlighting the findings of this study and providing further discussions informed by the critical questions raised in Chapter 1. After these discussions, this chapter gives a critical reflection on the use of the lesson study approach in developing and implementing the planned conceptual teaching strategy to teach a section of organic chemistry. While reflecting on the lesson study approach, the input evaluation from the participants will also be drawn to illuminate these reflections. Additionally, the chapter will focus on the limitations of this study, thus pointing out the rationale not to generalise the findings but to interpret them in context. In run down, the chapter concludes by focusing on the implications of this research on professional practice, curriculum policy positions, and recommendations for further studies in the field.

6.2 Further discussions

This section extrapolates from the findings made in Chapters 4 and 5 and unpacks them further to make sense of the results of this study in the context of existing literature. Three critical research questions were asked in line with this study's overall purpose, which was to develop and implement a conceptual teaching strategy in organic chemistry through the lesson study. These were: *What is the quality of teachers' pedagogical content knowledge in planning to teach a section of organic chemistry before the lesson study? What is a suitable conceptual teaching strategy for teaching a section of organic chemistry?How do teachers implement the conceptual teaching strategy developed through lesson study to teach a section of organic chemistry?*

To unpack the findings in response to the questions above, three constructs were identified: (i) *teachers' planned knowledge to teach organic chemistry before the lesson study intervention*, (ii) *teachers' planned knowledge to teach organic chemistry after the lesson study*, and (iii) *teachers' lesson enactment after engagements in the lesson study*.

6.2.1 Teachers' planned knowledge to teach organic chemistry before lesson study.

As indicated above, the first question aimed to investigate how teachers were engaged in lesson planning before the lesson study. To make sense of their knowledge for planning, the TSPCK model obtained from Mavhunga and Rollnick (2013) with its five content-specific components was instrumental in making sense of the data that was collected. Hence, the knowledge of teaching was understood from the perspectives of the TSPCK construct. Several studies in the literature have used this framework to look into teacher knowledge for teaching such as Mapulanga et al. (2023) on the topic of respiration in Life Sciences, Samuel et al. (2022) on the topic of particulate nature of matter in Natural Sciences, Dejene and Belachew (2023) on the topic of chemical kinetics and equilibrium and Ndlovu and Malcolm (2022) on the topic of stoichiometry in Chemistry.

The findings of this study revealed that teachers' planned knowledge from the perspectives of TSPCK in organic chemistry was generally limited before the exposure to the lesson study approach. These findings were similar to the work of Mapulanga et al. (2023) in which practising teachers were at a limited level of the planned TSPCK before the lesson study intervention on the topic of respiration. In contrast, in electrochemistry, Rollnick and Mavhunga (2014) found teachers to have an overall basic knowledge of TSPCK before the explicit intervention.

Whilst on lesson planning, Hidayat et al. (2020, p. 3) advocated that "*planning must start from setting goals to be achieved through a complete needs analysis and documents, then determining the steps that must be taken to achieve these goals*". In this study, this was not evident in the lesson plans analysed before the engagement of teachers in the lesson study approach. It was found that before the lesson study, teachers failed to determine the goals of the lesson explicitly. Furthermore, there was no evidence of teachers' activities on how the lesson was to be presented. Lastly, the activities to be given to learners to find out whether they mastered the concepts of organic reactions were excluded. This observation indicated poor knowledge of teaching.

In this study, the knowledge of planned students' prior knowledge was found to be limited. Such a finding concurs with the study by O'Brien (2017) in redox reactions conducted in New York for experienced teachers. O'Brien (2017) found that experienced teachers were unable to identify misconceptions about a topic. Similar to Mapulanga et al. (2023) in Zambia, they found that experienced teachers held limited knowledge of planned students' prior knowledge in respiration.

However, with pre-service teachers in the case of organic chemistry, Aydin et al. (2015) in Turkey found that teachers had some knowledge of students' misconceptions before the explicit practicum course. This study also revealed that participating teachers had different knowledge of curricular saliency (limited and basic) measured through the TSPCK rubric. Similarly, Samuel et al. (2022) reported that in-service teachers in their study had limited knowledge of curricular saliency before intervention. On the other hand, the work of Rollnick and Mavhunga (2014) in South Africa revealed that in-service teachers were at a developing level of curricular saliency.

Furthermore, this study revealed that the participating teachers were unaware of the component of what is difficult to teach. There was no evidence found in their lesson plans concerning this component. These results were in contrast with the findings of Aydin-Gunbatar et al. (2020) where pre-service teachers in Turkey were aware of learners' difficulties and alternative conceptions of the Cemistry content. Also, Ndlovu (2017) reported that pre-service teachers were at the basic level of what is difficult to teach in his study conducted on stoichiometry. In the studies conducted by Samuel et al. (2022), findings were different where their participants held basic developing knowledge of what is difficult to teach before the intervention. Furthermore, Mapulanga et al. (2023) reported that in-service teachers had limited knowledge of respiration in their study in Namibia before they were engaged in the lesson study approach.

The knowledge of representations was found to be limited before the lesson study intervention in this study. Vokwana (2013) reported challenges regarding this TSPCK component in organic chemistry. Challenges include that teachers need to know a variety of representations and be able to explain how they use those representations. Furthermore, teachers need to know the linkage between levels of representations, especially macroscopic levels. These reported findings by Vokwana (2013) on challenges experienced by teacherswere informed by the experiences of teachers TSPCK. The findings of this study were similar to the work of Koopman (2017) in investigating the three levels of representation where teachers failed to show links between those levels. Similar to the work of O'Brien (2017) in New York in TSPCK for experienced teachers in electrochemistry, teachers held limited knowledge of representations.

Lastly, the study revealed that in-service teachers had limited knowledge of a conceptual teaching strategy. These findings were quite different from those reported by Rollnick and Mavhunga (2014) where teachers were found to have developed exemplary levels of conceptual teaching strategy in teaching electrochemistry. For Samuel et al. (2022), in-service teachers were at the basic to developing levels of a conceptual teaching strategy in a particulate nature of matter. The next construct discusses the development of the conceptual teaching strategy in organic chemistry following the lesson study approach.

6.2.2 Teachers' planned knowledge to teach organic chemistry after the lesson study

The findings of this study revealed that teachers' planned knowledge for teaching organic chemistry was significantly developed. Each component of planned TSPCK during the first and second lesson study cycles across three big ideas selected was developed during this reported study. Based on discussions presented in 6.2.1, it was revealed that the overall planned knowledge for the teaching section of organic chemistry was limited. These reported developments were compared to that planned knowledge before the lesson study approach as well as the first and the second lesson study cycles. These findings were in line with those reported by Rollnick and Mavhunga (2014) in PCK for teaching electrochemistry where planned knowledge was developed. Similar findings were also reported in the works of Lucenario et al. (2016) in a study about pedagogical content knowledge in Chemistry where "*respondents improved their competencies after the intervention"*. Similarly, Mesci et al. (2020, p. 757), in the study of developing lesson plans, reported that *"following the PCK-based NOS* (nature of scientific) *instruction, almost all of the PSTs demonstrated the better-developed understanding of NOS, and they successfully maintained their informed views in the long term*". The TSPCK construct underpinned these developments. Likewise, Samuel et al. (2022) stated a positive shift in all components of TSPCK in teaching the particulate nature of matter after the intervention. Besides, Mapulanga et al. (2023) claimed the same findings where teachers developed their planned knowledge of teaching respiration. In contrast to these findings, Rollnick et al. (2008), in a study conducted on teaching the mole concept, revealed that participating teachers lacked connections between big ideas after the intervention.

For students' prior knowledge, the findings revealed that participants identified misconceptions. They further draw for other components, meaning representations, when planning how those misconceptions will be addressed. These findings concur with the requirements for the knowledge of students' prior knowledge according to the rubric of Mavhunga and Rollnick (2013) in Appendix A, which stipulates that teachers must be "*able to consider students' misconceptions* *and draw on what students know from other taught concepts in previous topics and previous grades*". This was not evident before the lesson study approach in these participants. According to Bryan (2007, p. 1), "*Identification of misconceptions allows teachers to clarify them with the students as well as to reflect on their teaching pedagogy".* Based on this assertion, participants developed a conceptual teaching strategy that addresses students' misconceptions.

For curricular saliency, the participants identified five big ideas for the topic of organic reactions of which three of these were analysed, and further specified the importance of teaching those big ideas. Participating teachers specified the information that was not to be taught in this grade though they knew it. These findings also concur with those reported by Aydin-Gunbatar and Akin (2022) where pre-service teachers improved their knowledge of identifying big ideas in Chemistry. Furthermore, these findings were similar to O'Brien (2017) findings in New York who reported that participants displayed a foremost understanding of the curriculum and further delivered a real-life application of the importance of learning Chemistry. Akinyemi and Mavhunga (2021) also reported a positive shift from basic to exemplary in the development of curricular saliency in the study of organic chemistry. Additionally, Mapulanga et al. (2023) concur with these findings where in-service teachers developed the planned knowledge of curricular saliency in respiration.

These participating teachers identified what is difficult to teach in organic reactions. Furthermore, they drew from other components of TSPCK and made a linkage of TSPCK components when planning within this component. These findings are similar to Ndlovu (2017) findings which reported that pre-service teachers improved from basic knowledge to developing knowledge of representations in developing TSPCK in stoichiometry, which is similar to Mapulanga et al. (2023) who reported a shift from limited to exemplary in the planned knowledge of representations in respiration. The knowledge of representations was dramatically improved in this reported study. Participating teachers considered three levels of representation and showed linkage between these levels. Moreover, the study revealed that planned representations further addressed students' misconceptions.

The planned conceptual teaching strategy for participants was developed during the lesson study approach. The components of TSPCK were at interplay during the development stage of the conceptual teaching strategy within this study. These findings were similar to the study conducted in respiration by Mapulanga et al. (2023) where in-service teachers had a positive shift of development in planned knowledge of conceptual teaching strategy. In contrast to these findings, teachers remained at the same levels in pre and post-tests in the study conducted by Samuel et al. (2022) on the particulate nature of matter. As proposed by Rocco and Plakhotnik (2009, p. 127), a "*theoretical framework synthesises existing theories and related concepts and empirical research to develop a foundation of new theory development*". Though the study did not aim to develop a new theory, a new conceptual teaching strategy to teach organic reactions was developed through the underpinning of the theoretical construct of Mavhunga (2020). The next subheading focused on the implementation of a developed conceptual teaching strategy.

6.2.3 Implementation of a developed conceptual teaching strategy after engagement with a lesson study approach

The study revealed that knowledge of lesson enactment was developed after engagement with lesson study cycles. At this stage, the enacted TSPCK was observed during the first and second stages of lesson study cycles and without comparing with personally enacted TSPCK for teachers before lesson study. These findings were similar to the work of Mapulanga et al. (2023) and Samuel et al. (2022) where enacted TSPCK for teachers was developed after interventions. Participating teachers showed development in all components of TSPCK from the first to the second lesson presentation during the lesson study approach. The shift from the first lesson enacted to the second lesson enacted showed a positive shift from basic to exemplary knowledge of enacted student prior knowledge. It enacted curricular saliency, and a positive shift from basic to developing knowledge of enacted of what is difficult to teach, knowledge of enacted representations, and knowledge of enacted conceptual teaching strategy. These findings support the work of Akinyemi and Mavhunga (2021, p. 297) who asserted that the "*purpose of the developing teacher knowledge for teaching is to improve the quality of classroom instruction, and ultimately learner achievement*". This assertion was evident in this study. Teachers' knowledge of enacting lessons in organic chemistry was improved and one of the participants confirmed that learners' performance was improved after engaging in professional development, the lesson study.

The above findings are similar to the work of Samuel et al. (2022) where teachers had a positive shift in all components of TSPCK in teaching the particulate nature of matter in Natural Sciences after an intervention. In contrast, Ndlovu (2017) reported a positive shift from basic to developing knowledge in all components of TSPCK, except in knowledge of representations where there was a positive shift from basic to exemplary in the development of TSPCK of pre-service teachers in stoichiometry. Similar to this study, Mapulanga et al. (2023) revealed that teachers developed their knowledge of teaching respiration after engagement in the lesson study where findings showed a positive shift from limited to developing knowledge of enacted curricular saliency, knowledge of enacted what is difficult to teach, and a knowledge of enacted conceptual teaching strategy, except for students' prior knowledge where there is a positive shift from limited to basic knowledge. For knowledge of enacted representations, Mapulanga et al. (2023) asserted that participants shifted from limited to exemplary knowledge. The next subtopic reflects on the effects of using a lesson study approach in planning and developing a conceptual teaching strategy in organic chemistry.

6.3 Critical Reflections

6.3.1 Conducting the Lesson Study

The main aim of this study was to develop and implement a conceptual teaching strategy in organic chemistry through a lesson study approach. Teachers' knowledge of planning and enacting TSPCK in organic chemistry was improved after the intervention of the lesson study. These findings concur with what other scholars have reported and to mention a few, Coenders and Verhoef (2019) in the beginning and experienced teachers in stoichiometry in the Netherlands, Joubert et al. (2020) in the use of technology in teaching different topics of all fields, including mathematics in South Africa and Botswana and Mapulanga et al. (2023) in teaching respiration in Namibia.

The study findings valued the use of the lesson study approach in developing and implementing a conceptual teaching strategy in a section of organic chemistry. Most of the things participants valued in lesson study are its nature of useful, effective, and productive, exposure that allows teachers to develop TSPCK, attend to the gaps and provide a variety of students' misconceptions, helping with the implantation of departmental policies, and a way of providing information that enables students to pass in examinations thus by improving pass rate. These findings of this study concur with the work of Ono and Ferreira (2010). The next section reflects on the use of CoRe when planning to teach a section of organic chemistry.

Given the opportunity to re-conduct this study in the future, I would observe the lesson enactment for participants from the lesson plans used before the lesson study intervention. This will enable the researcher to know their personal planned and enacted TSPCK before the intervention. Also, this would enhance the researcher to compare personal TSPCK with collective TSPCK to measure the effectiveness of the lesson study approach in-depth. Secondly, I would consider selecting more experienced and less/no experienced in-service teachers as participants. This will bridge the gap of teaching between experienced and less/no experienced teachers. Then, this would be compared with the findings reported by Buma and Sibanda (2022, p. 116) that "*TSPCK for pre-service teachers was found more than for in-service teachers*". These authors surmised that "*they had been previously exposed to the topic and specific components*".

6.3.2 Planning through the use of the Content Representations (CoRe)

Content representations tool was used in this study to capture and portray Physical Sciences' in-service teachers' PCK for planning to teach organic reactions. The CoRe tool was found valuable in dealing with learners' misconceptions about organic reactions. Also, the CoRe tool gave clear guidance on the identification of big ideas, reasons for teaching big ideas, and the extent to teach specific big ideas. Furthermore, the CoRe tool is equipped to identify the difficulties in organic chemistry and how to address those difficulties. Moreover, a CoRe tool assisted in planning representations and analogies to be used in classroom settings. Lastly, the CoRe tool assisted participating teachers in integrating all components of TSPCK which gave rise to the conceptual teaching strategies to teach organic reactions.

In a study *in search of pedagogical content knowledge in science,* Loughran et al. (2004) in Singapore developed a CoRe tool with Pedagogical and Professional experience Repertoires. Most scholars have used this tool in different topics and different disciplines. These scholars include Rollnick et al. (2008) in a study about the place of subject matter in knowledge in PCK, Mavhunga and Rollnick (2013) on the topic of electrochemistry, and Mapulanga et al. (2023) on the topic of respiration. The next sub-topics are the limitations of this study.

6.4 Limitations of the study

Due to the vast nature of the topic of organic chemistry, the focus was only based on organic reactions and only three big ideas. This limited the exploration of the topic in its entirety. Thus, the findings made in this study cannot be generalised. However, they were interpreted in the context in which the study was conducted. The time factor also limited the meetings between the participants in developing more teaching strategies for teaching organic reactions. Lastly, another challenge was the availability of chemicals for performing practical reaction experiments. The exploration of these reactions was done theoretically. Only three lesson cycles were managed due to the time factor. The first cycle gave rise to the first lesson, the second cycle birthed the second lesson, and the last cycle to reflect on the use of CoRe and the effects of the lesson study approach.

6.5 Conclusion

In conclusion, this study identified several gaps in teachers' knowledge of lesson planning in the case of organic chemistry. Most of the common practices observed indicated poor levels of TSPCK. The exposure to the lesson study allowed teachers to collaboratively develop a conceptual teaching strategy for addressing misconceptions and developed CoRe-based lessons that teachers may take into classes to teach organic reactions. This study was informed by topic-specific knowledge for teaching and hypothesised that specific topics in science require idiosyncratic conceptual teaching strategy. The lesson study approach provided possibilities and opportunities for developing the conceptual teaching strategy in organic chemistry. The implementation and reflections generated improved the quality of this conceptual teaching strategy. The use of the CoRe tool to capture and portray in-service teachers' TSPCK in organic reactions showed good reliability. This tool was also found to be valid by other scholars like Mavhunga (2018) and Buma and Sibanda (2022).

6.6 Recommendations

Regarding professional practice, this study recommended the application of the lesson study in the continuous teacher professional development in all clustering schools to ensure equivalent content delivery to learners who write common examinations such as NSC. Furthermore, the use of lesson planning templates from the Department of Education was found to be limited and did not allow teachers to delve explicitly into the PCK. Hence, this study recommends the use of the CoRe as a common planning template in schools. For further research, this study recommends the exploration of conceptual teaching strategies with other difficult science topics such as equilibrium, acids and bases, and stoichiometry.

6.7 Final Pierce

The TSPCK model proved to be an effective tool for describing the quality of conceptual teaching strategies. The perspectives expressed by numerous academics in the TSCPK literature on how the other four components worked together to affect the conceptual teaching method were determined to be true and guided this effort. This study discovered that instructors' anticipated knowledge of teaching an organic chemistry section was inadequate before engaging in the lesson study. This demonstrates, among other things, the limitations of the existing lesson plans utilised in South African schools. This work has demonstrated that conceptual teaching techniques may be systematically designed to inform conceptual teaching in science using the CoRe and the affordances of a lesson study approach to lesson development.

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Appendices

Appendix A: Adapted TSPCK-based CoRe

To be developed for each Big Idea
A. Curricular Saliency
A1. What do you intend students to learn about this idea? (in original CoRe) A2. Why is it important for students to know this? (in original CoRe) A3. Which concepts need to be taught before this big idea? (only in adapted CoRe) What else do you know about this idea that you don't intend students to know yet? (in original CoRe)
B. What makes a topic easy or difficult to understand
B1. What do you consider easy or difficult about teaching this idea? (original CoRe: Difficulties/limitations connected with teaching this idea)

C. Learner Prior Knowledge
C1. What are typical students' misconceptions when teaching this idea? (original CoRe: Knowledge about students' thinking that influences your teaching of this idea)
D. Conceptual Teaching Strategies
D1. What effective teaching strategies would you use to teach this big idea? D2: Which questions would you consider important to ask in your teaching strategy? (original CoRe: teaching procedures)
E. Representations
E1 Which representations would you use in your teaching strategy? (only in adapted CoRe)
Additional Questions not linked to a specific component What ways would you use to assess students' understanding? (original CoRe: Specific ways of ascertaining understanding) Which aspects of teaching and planning for this big idea would you like to reflect on? (only in adapted CoRe

Appendix B: A Rubric for planned TSPCK

	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
Learner Prior knowledge	• No identification/ No acknowledgment/no consideration of students' prior knowledge or misconceptions. • No attempt to address the misconceptions.	• Identifies misconceptions or prior knowledge. • Provides standardized definition as a means to counteract the misconception. • No evidence of drawing on other TSPCK components.	• Identifies misconceptions and prior knowledge. • Provides standardized knowledge as a definition. • Expands and re-phrases explanation using the other component of TSPCK interactively.	• Identifies misconceptions or prior knowledge. • Provide standardized knowledge as the definition • Expands and re-phrases explanation/ conforms accurate understanding, drawing on interactively two or more other components of TSPCK.
Curriculum Saliency	• Identified concepts are a mix of Big Ideas and subordinate ideas. • Identified pre-concepts are far from the topic.	• Identifies at least 3 Big Ideas. • Not all 3 Big Ideas' subordinate concepts were identified. • Suggested sequencing has one or two illogical placing of Big Ideas. • Identified pre-concepts are far from the current topic. • Reasons given for the importance of the topic exclude conceptual considerations and show no evidence of drawing on other TSPCK components.	• Identifies at least 3 Big Ideas. • Subordinate concepts correctly identified for all Big Ideas. • Provides logical sequence. • Identifies pre-concepts relevant to the topic. • Reasons given for the topic the importance include reference to conceptual scaffolding/sequential development drawing on one other TSPCK component.	• Identifies at least 3 Big Ideas. • Subordinate concepts correctly identified for all Big Ideas with explanatory notes. • Provides a logical sequence of all 3 Big Ideas and logical reasons. • Identifies pre-concepts relevant to the current topic and explanation given. • Reasons given for the importance of the topic include conceptual scaffolding concerning other TSPCK components. e.g. learner's prior knowledge and what makes it difficult.
What makes the topic difficult?	• Identifies broad topics without reasons and specifies the actual sub-concepts that are problematic.	• Identifies specific concepts but provides broad generic reasons such as 'abstract'	• Identifies topic concepts leading to learner difficulty. • Reasons given relate to one other TSPCK component.	• Identifies specific concepts with reasons linking to specific gatekeeping concepts and TSPCK components such as prior knowledge and aspects of curricular saliency.
Representations	• Limited to use of only macroscopic (analogies, demos, etc.) representation with no explanation of specific links to the concept presented.	• 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 scientific symbolic representation with explanatory notes linking the two representations to the aspect(s) of the concept being explained. • Use of the above representations in combination concerning other TSPCK components. e.g. learner prior knowledge.	• Use of macroscopic representation with sub-microscopic representation to enforce a specific aspect. • Explicit link to other components of TSPCK e.g. emphasis on a core aspect of CK demonstrated in the representations and learner prior knowledge.
Teaching strategies	• No evidence of acknowledgement of the students' prior knowledge and misconceptions. • Lacks aspects of curriculum saliency • Use of representations limited to macroscopic or symbolic or scientific symbolic representations.	• Acknowledges students' misconceptions verbally with no corresponding confrontation strategy. • Lacks curricular saliency. • Use of macroscopic and symbolic representations with no linking explanatory notes.	• Considers confirmation and confrontation of students' prior knowledge and/or misconceptions. • Considers at least one aspect related to curricular 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.	• Consider students' prior knowledge and evidence of confrontation of misconceptions. • Considers at least two aspects related to curricular saliency: sequencing what not to discuss of important conceptual aspects etc. • Use either the macroscopic or symbolic representation with sub-microscopic representation to enforce understanding and may show awareness of learner difficulty

Appendix C: A rubric for enacted TSPCK

Prompt	Level of TSPCK enactment				
	Very limited (0)	Limited (1)	Basic (2)	Developing (3)	Exemplary (4)
2.	• Not answered	• Identified concepts are key ideas or a mix of key ideas and subordinate ideas	• At least one identified concept indicates the science content to be learned	• Two or more identified concepts indicate the science content to be learned	• All identified concepts indicate the science content to be learned
3.	• Not answered	• Reason(s) given are generic benefits of education	• Reasons given for the importance of topic exclude conceptual considerations and show no evidence of integrating other TSPCK components	• Reasons given for importance of the topic include reference to conceptual consideration and show evidence of integrating other TSPCK component e.g. what makes topic difficult	Reasons given for importance of the topic include reference to conceptual consideration and show evidence of integrating other TSPCK component e.g. what makes topic difficult
4.	• Not answered	• Identified concepts are relevant to the topic of respiration but not pre-requisites to the chosen idea	• At least one identified concept is a pre-requisites to the chosen idea	• Two or more identified concepts are pre-requisites to the chosen idea	• All identified concepts are pre-requisites to the chosen idea
5.	• Not answered	• Identified concepts are not relevant for current topic/ grade level of learners	• Identified concepts are not relevant to the current key idea but relevant to the grade level of learners	• Identified concepts are relevant to the current key idea and grade level of learners i.e. relevant for current level of learners	• Identified concepts are within the grade level of learners i.e. relevant for current level of learners
6.	• Not answered	• 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 component	• Identifies specific concepts with reasons linking to specific gate keeping concepts and to TSPCK components such as prior knowledge and aspects of curricular saliency

7.	• Not answered	• **No identification misconceptions/alternative conception (stated answer does not represent a misconception)**	• **Identifies at least one misconception/alternative conception but does not provide a standardized definition or reason for it**	• **Identifies two misconceptions/alternative conceptions and provides a standardized definition or reason for one or both**	• **Identifies three or more misconceptions/alternative conceptions and provides a standardized definition or reason for them**
8.	• Not answered	• Identified teaching strategies without a description of how they would be used	• Identified teaching strategies with a limited description of how they would be used. Considers at least one aspect related to concepts to be learned	• Identified teaching strategies with a clear description of how they would be used. Considers at least one aspect related concepts to be learned	• Identified teaching strategies with an explicit description of how they would be used. Considers at least one aspect related to curricular saliency (Concepts to be learned)
9.	• Not answered	• No link to curricular saliency or relevant learning theory	• Limited link between strategy and curricular saliency (concepts to be learned) or relevant learning theory	• Clear link between the strategy/strategies and the concepts to be learned or relevant learning theory	• Explicit link between the strategy/strategies and the concepts to be learned or relevant learning theory or relevant learning theory
10.	• Not answered	• Limited to use only macroscopic representations (analogies, demonstrations etc.) representation with no explanation of specific links to the concepts represented	• Use of macroscopic representation (analogies, demonstrations etc.) without explanatory notes to make the links to the aspects of the specific concept being explained	• Use of macroscopic representation with explanatory notes linking the representations to aspect(s) of the concept being explained or relevant learning theory/TSPCK component	• Use of macroscopic representation with sub-microscopic representation to enforce a specific aspect of the concept. Makes explicit link(s) to relevant learning theory/TSPCK component
11.	• Not answered	• No link between the representation(s) and the concepts to be learned • No link to relevant learning theory	• Limited link between the representation(s) and the concepts to be learned and • Links to relevant learning theory	• Clear link between the representation and the concepts to be learned, with reference to other TSPCK components or relevant learning theory	• Explicit link between the representation and the concepts to be learned, with reference to other TSPCK components or relevant learning theory

Appendix D: Reflective questionnaire

Evaluating the effectiveness of using lesson study when planning to teach organic chemistry.

1. How did you find collective planning during lesson study compared to personal planning when planning to teach organic chemistry?

2. How ca you value the effect of using lesson study approach when enacting collective planned lesson?

3. Can you recommend usage of the lesson study approach in other topics in your discipline?

Appendix E: Informed consent letter

Science and Technology Cluster,
School of Education,
College of Humanities,
University of KwaZulu-Natal,
Edgewood Campus, KwaZulu Natal
Date

Dear grade 12 Physical Sciences teacher

INFORMED CONSENT LETTER for Master student in science education

My name is Sphesihle Winile Nsele. I am a **Master** student from the Science and Technology Cluster, School of Education, College of Humanities, University of KwaZulu-Natal. I am conducting research titled **'Developing and Implementing Conceptual Teaching Strategy in Organic Chemistry through Lesson Study'.**

The literature shows that most studies on conceptual teaching strategies in organic chemistry foc on university level contexts. Also, studies on organic chemistry mostly focused on pre-se teachers (PSTs). The studies mostly explored the following areas: moving some class activiti homework to increase time for attending to students' difficulties; pedagogy for the teaching of org chemistry; and conceptual understanding of chemistry and classroom implications.

This study intends to explore the development of conceptual teaching strategies in organic chemistry in selected South African schools.

The objectives of the research are as follows:

- to collaboratively develop a suitable conceptual teaching strategy to teach organic chemistry through lesson study;
- to assess teacher implementation of the conceptual teaching strategy developed through lesson study; and
- to examine the effects of the lesson study approach on developing and implementing a conceptual teaching strategies in organic chemistry.

You are invited to please participate in the study because you are a grade 12 Physical Sciences teacher. I am requesting you to participate in Lesson Study where we will be developing and implementing conceptual teaching strategies in organic chemistry. The main focus will be in five lessons in organic reactions since it is the most poorly performed topic in organic chemistry.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee
Please note that:

- Your participation is voluntary. There will be no charge against you if you do not participate.
- Your confidentiality is guaranteed as your inputs will not be attributed to you in person, but reported only as a population member opinion.
- The lesson study and individual interviews (1 of each) will last for about an hour.
- Lessons may be split depending on your preference.
- The lesson will be observed by a researcher.
- Any information given by you cannot be used against you, and the generated data will be for the purposes of this research only.
- Data will be in the form of interview transcripts and voice records, and will be stored in se storage and destroyed after 5 years.
- You have a choice to participate, not participate or stop participating in the research. You will not be penalized for taking such an action.
- The research aims at developing, implementing, and evaluating conceptual teaching strate in organic chemistry through lesson study.

- Your involvement is purely for academic purposes only, and there are **no financial** benefits involved. However, it is expected that you will enhance understanding of conceptual teaching strategies and the use of lesson study to develop, implement, and reflect on conceptual teaching strategies.

Thank you

Yours faithfully

……………………..

My contact details are as follows:

[redacted]

My supervisor is Dr BP Ndlovu. He is a member of staff in the School of Education, Colleg Humanities, Edgewood Campus, University of KwaZulu-Natal

My supervisor's contact details are:

[redacted]

[redacted]

Thank you for reading this document about this research.

DECLARATION OF CONSENT

I .... (Full names of participant) hereby confirm that I have been informed about the study titled '**Developing and Implementing Conceptual Teaching Strategy in Organic Chemistry through Lesson Study'** by **Sphesihle Winile Nsele**. **I understand the contents of this document and the nature of the research project, and I consent to participating in the research project.**

I understand the purpose and procedures of the study.
I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.
I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.
I voluntarily give permission to participate in lesson study.

I give consent for voice recording during my lesson implementation.

I give permission for my reflective lesson plans and lesson implementation be used as a source of data.

My identity will not be disclosed and pseudonyms will be used to protect my identity

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at [redacted] / [redacted].
If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

[redacted]

Additional consent, where applicable

- I am willing to be part of the lesson study in organic chemistry and interviews. I am willing to allow cellphone recording, and the use of lesson plan for data:

	Willing	Not willing
Cellphone recording of interviews		
A part of lesson study		
Use of lesson plans		

……………………………………...

Name of Participant

………………………………………… ……………………………………

Signature of Participant **Date**

Appendix F: Department of Kwa-Zulu Natal permission letter to conduct study

KWAZULU-NATAL PROVINCE
EDUCATION
REPUBLIC OF SOUTH AFRICA

OFFICE OF THE HEAD OF DEPARTMENT

[redacted]

Enquiries: Mrs B.T. Ntuli **Ref.**:2/4/8/7457

[redacted]

Dear Mrs Nsele

PERMISSION TO CONDUCT RESEARCH IN THE KZN DoE INSTITUTIONS

Your application to conduct research entitled: **"DEVELOPING AND IMPLEMENTING CONCEPTUAL TEACHING STRATEGY IN ORGANIC CHEMISTRY THROUGH LESSON STUDY",** in the KwaZulu-Natal Department of Education institutions has been approved. The conditions of the approval are as follows:

1. The researcher will make all the arrangements concerning the research and interviews.
2. The researcher must ensure that Educator and learning programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, Educators, Schools and Institutions are not identifiable in any way from the results of the research.
5. A copy of this letter is submitted to District Managers, Principals and Heads of Institutions where the Intended research and interviews are to be conducted.
6. The period of investigation is limited to the period from **20th April 2023 to 31st December 2025**.
7. Your research and interviews will be limited to the schools you have proposed and approved by the Head of Department. Please note that Principals, Educators, Departmental Officials and Learners are under no obligation to participate or assist you in your investigation.
8. Should you wish to extend the period of your survey at the school(s), please contact Mrs Buyi Ntuli at the contact numbers above.
9. Upon completion of the research, a brief summary of the findings, recommendations or a full report/dissertation/thesis must be submitted to the research office of the Department. Please address it to The Office of the HOD, Private Bag X9137, Pietermaritzburg, 3200.
10. Please note that your research and interviews will be limited to schools and institutions in KwaZulu-Natal Department of Education.

[redacted]

Mr GN Ngcobo
Head of Department: Education
Date: 20th April 2023

GROWING KWAZULU-NATAL TOGETHER

Appendix G: Permission letter from circuit manager

kzn education

PERMISSION LETTER

I Nxumalo L.B. .... **(Full names** **Hlabisa CMC manager) hereby confirm that** I have been informed about the study titl **'Developing and Implementing Conceptual Teaching Strategy in Organic Chemistı through Lesson Study'. I understand the contents of this document and the nature of tl research project, and I consent for the Physical Sciences teachers in selected schools participate in the research project. I also consent to the following data collection too (please tick):**

	Yes	No
Interviews	✓	
Audio/video recordings	✓	
Discussions	✓	

[redacted]

07/03/2023

Date

Appendix H: UKZN Ethics Clearance certificate

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

14 April 2023

Sphesihle Winile Nsele [redacted]
School Of Education
Edgewood Campus

Dear SW Nsele,

Protocol reference number: HSSREC/00005272/2023
Project title: Developing and implementing conceptual teaching strategy in Organic Chemistry through lesson study
Degree: Masters

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 09 February 2023 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

<u>This approval is valid until 14 April 2024.</u>
To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

HSSREC is registered with the South African National Health Research Ethics Council (REC-040414-040).

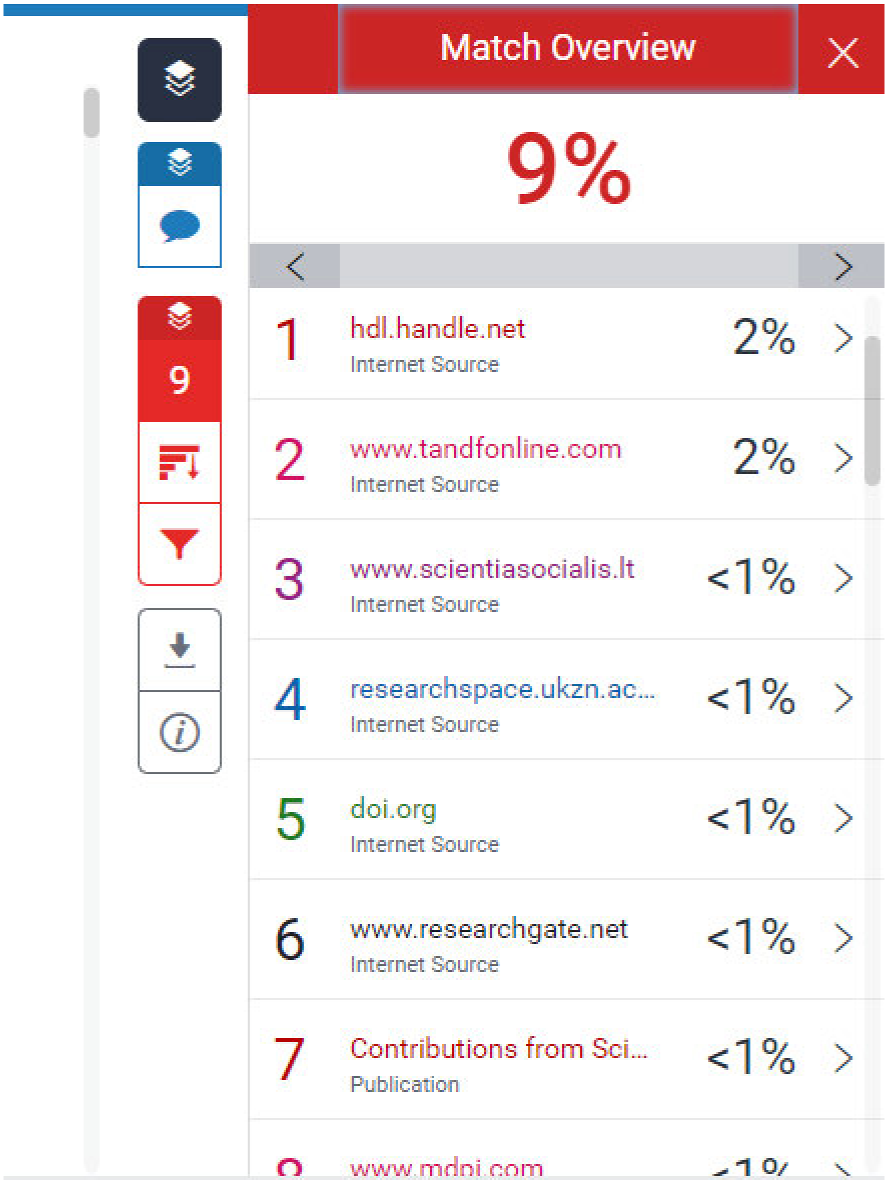
Yours sincerely,

[redacted]

Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee
Postal Address: Private Bag X54001, Durban, 4000, South Africa
Telephone: +27 (0)31 260 8350/4557/3587 **Email:** hssrec@ukzn.ac.za **Website:** http://research.ukzn.ac.za/Research-Ethics
Founding Campuses: Edgewood Howard College Medical School Pietermaritzburg Westville



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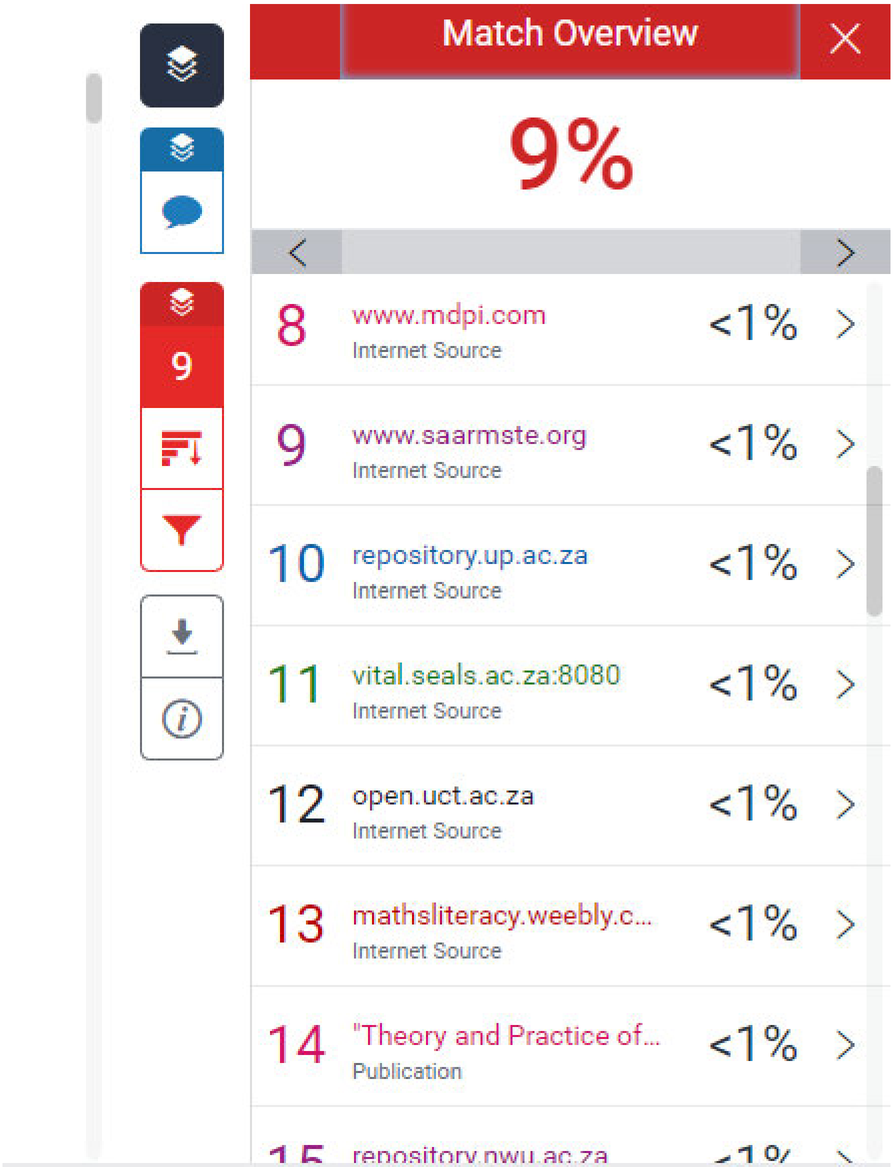
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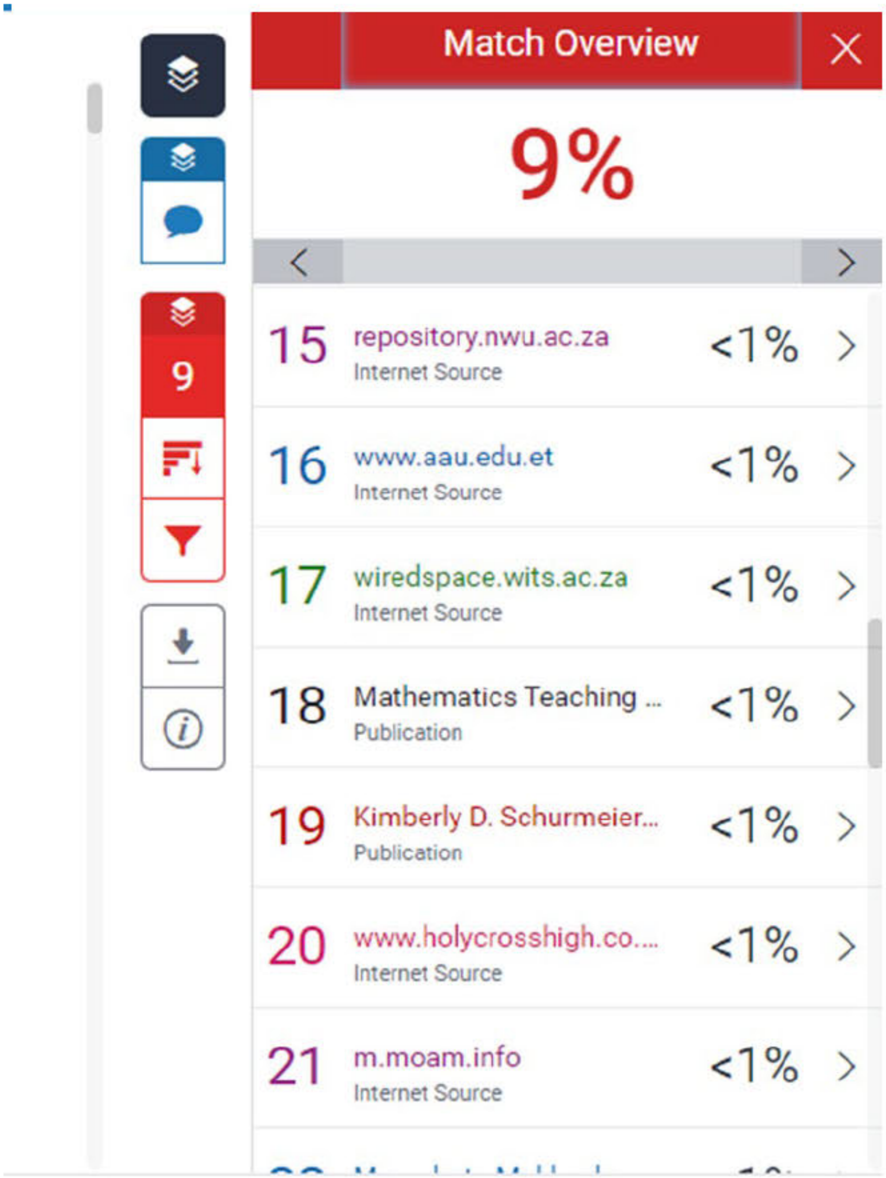
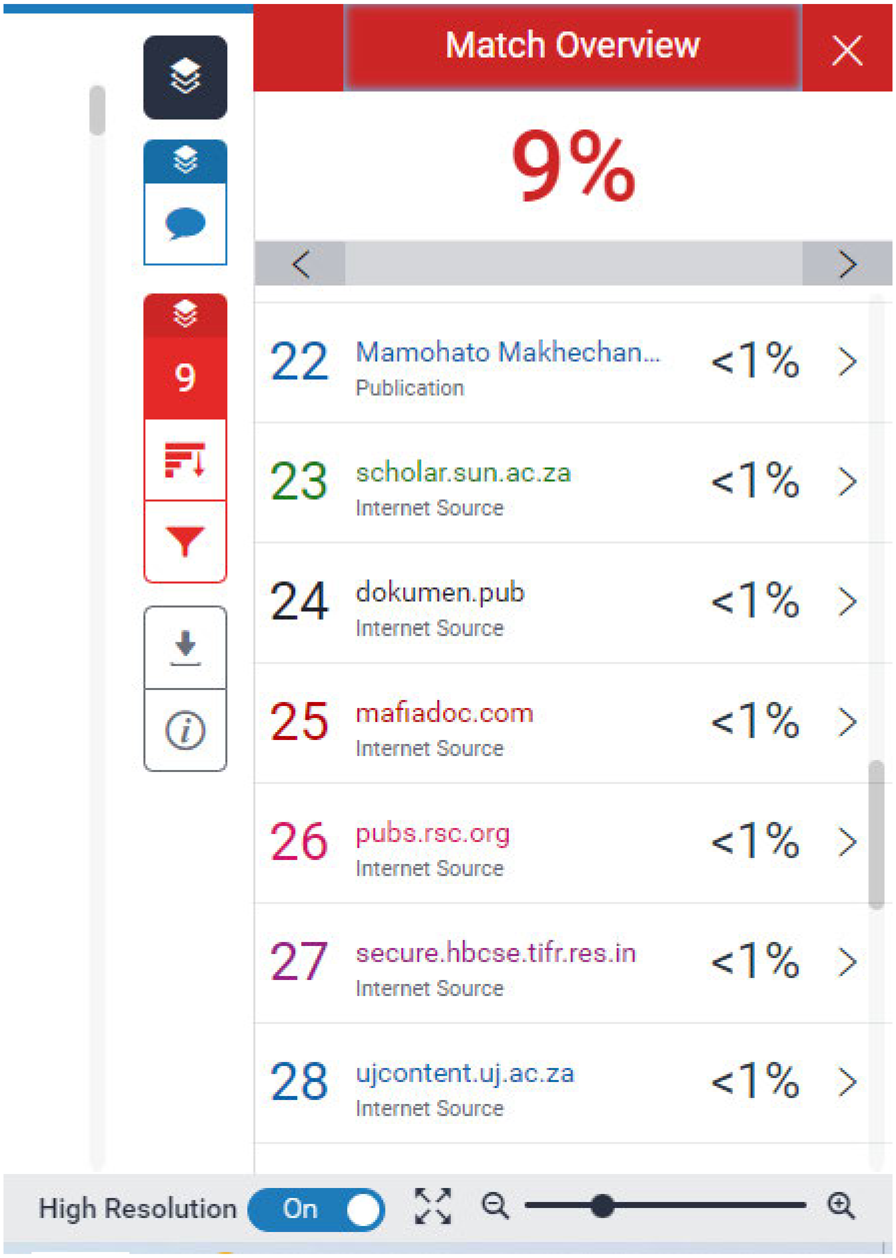
Appendix I: Similarity Report

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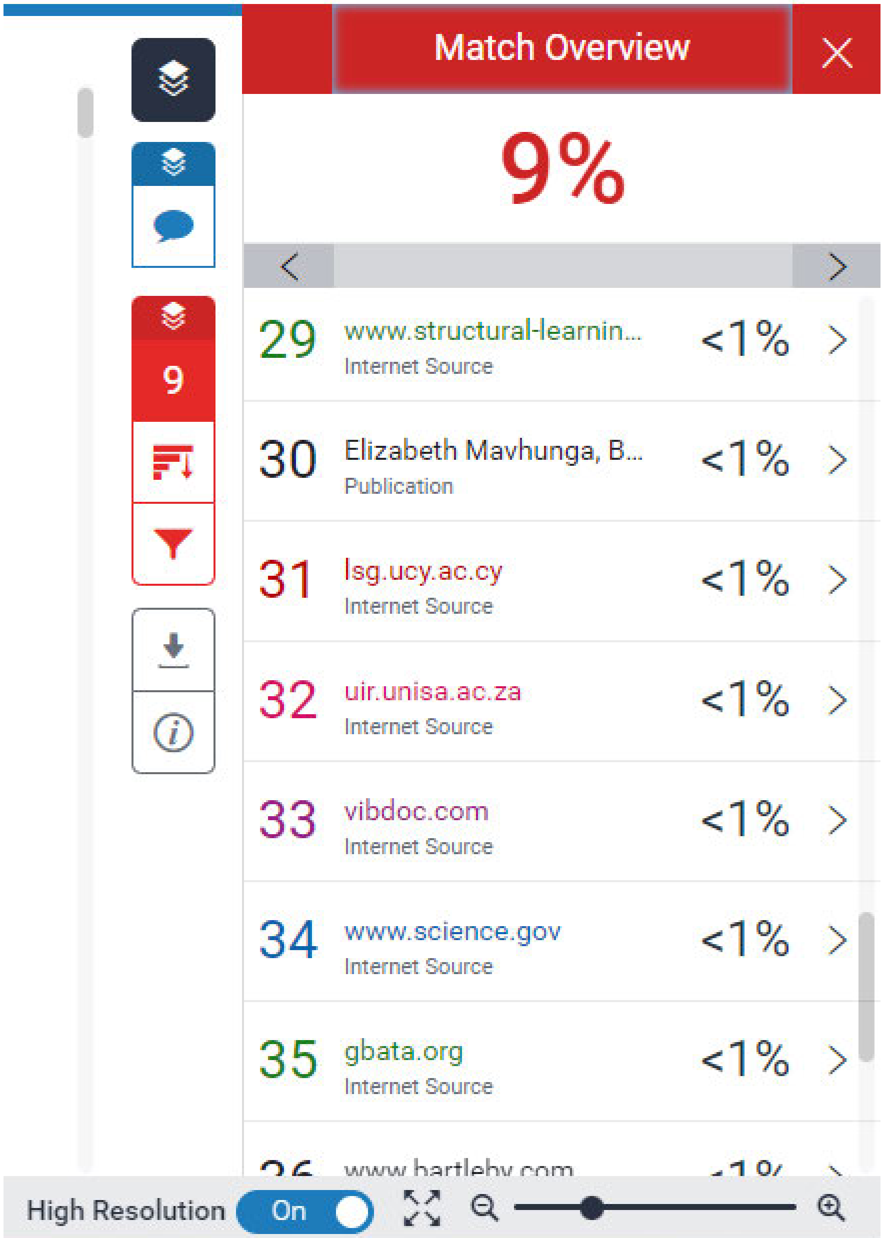
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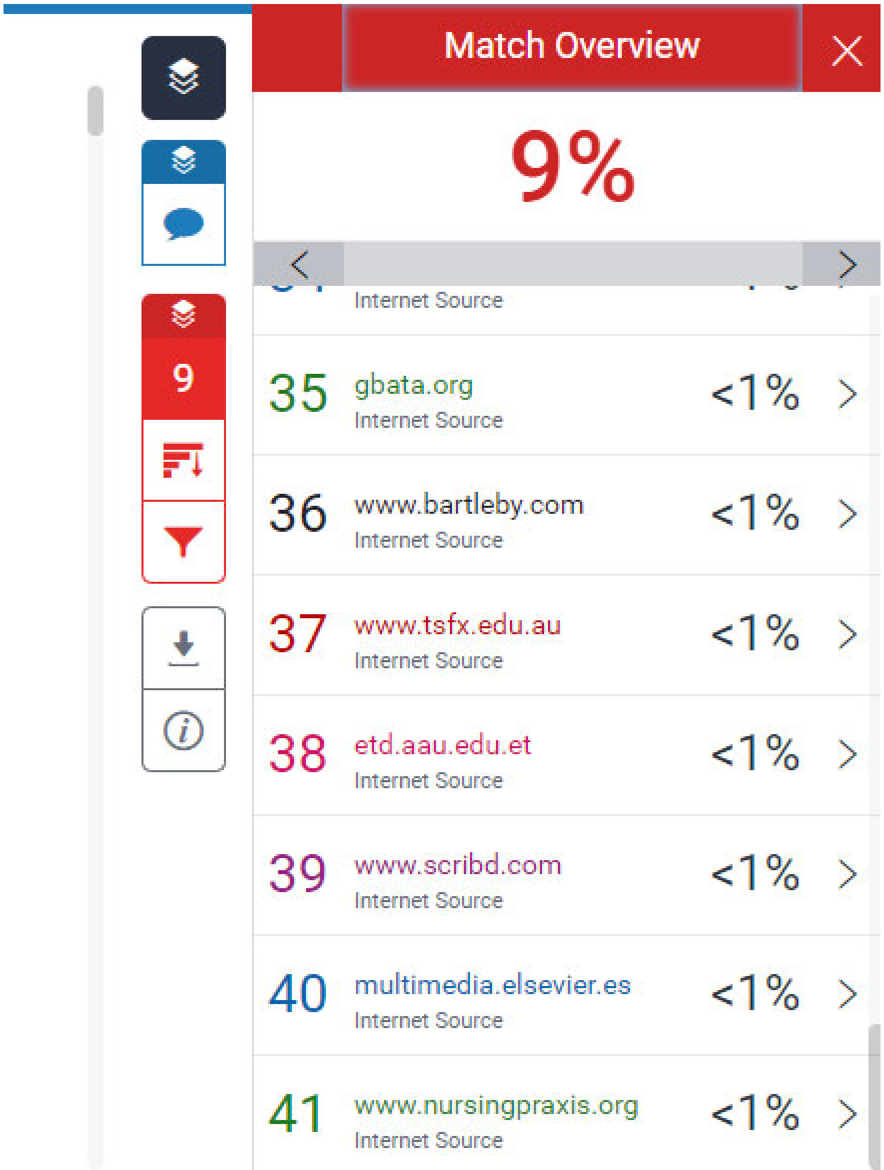
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25 November 2023

DEVELOPING AND IMPLEMENTING CONCEPTUAL TEACHING STRATEGY IN ORGANIC CHEMISTRY THROUGH LESSON STUDY

This confirms that I edited substantively the above document, including a Reference list. The document was returned to the authors with various tracked changes intended to correct errors and clarify meaning. It was the authors's responsibility to attend to these changes.

Yours faithfully

[redacted]

Dr. K. Zano

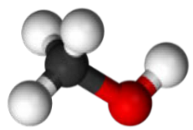
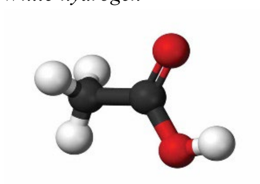
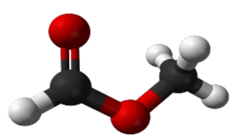
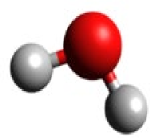
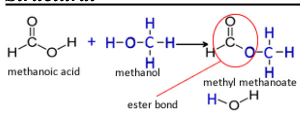
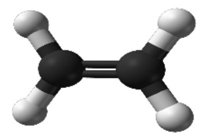
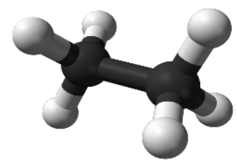
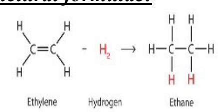
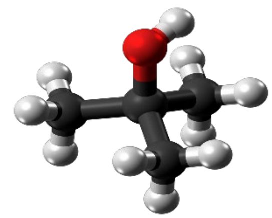
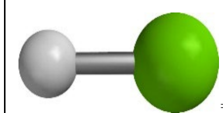
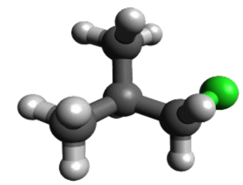
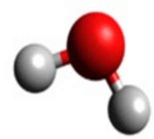
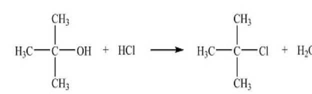
Ph.D. in English

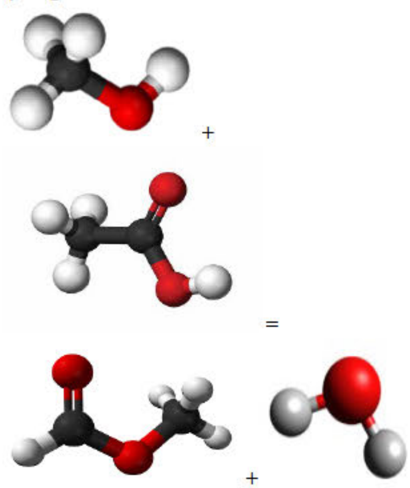
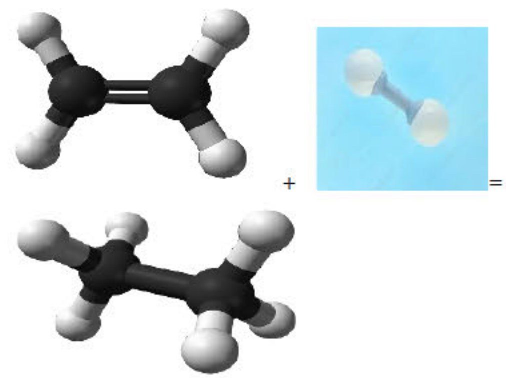
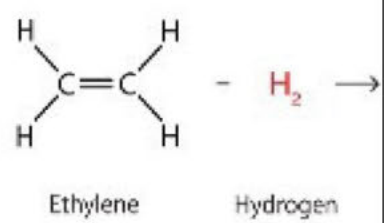
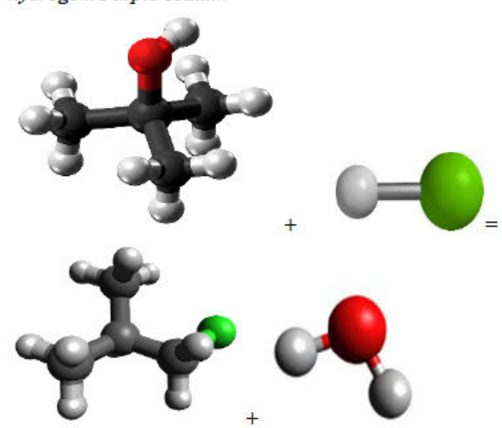
[redacted]

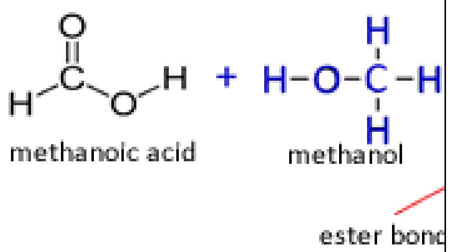
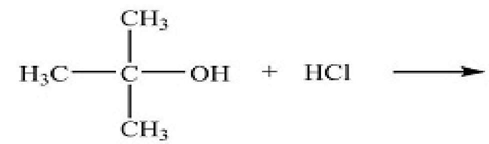
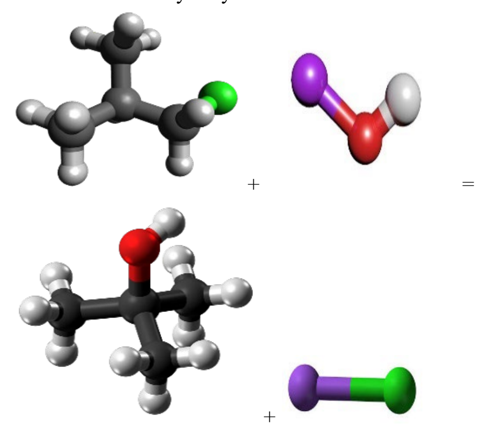
Appendix K: Developed conceptual teaching strategy

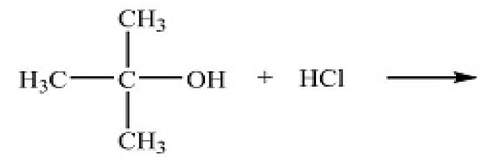
	Big idea 1 An ester is a product of an acid-catalyzed condensation reaction between an alcohol and a carboxylic acid	**Big idea 2** Unsaturated compounds undergo an addition reaction	**Big idea 3** Interconversion between alcohol and haloalkanes
What are typical students'' misconceptions when teaching this idea?	• Learners drink different fruity flavors of fruit juice or sweets thinking it is made out of those fruits but its flavors are made out of esters. • Vinegar is used to be found in households but learners are not aware that it is acetic acid.	• Learners are familiar with the types of alcohol produced alcohol in the community, learners may tend to compare alcohol produced during hydration reaction with what is produced in their communities. • Production of a major product according to Markovnikov's rule can be confused with a minor product. For example $\text{but} - 2 - \text{ene} + \text{hudrogen bromide} \rightarrow 2 - \text{bromobutane}$ (major product) • $\text{bu} - 2 - \text{ene} + \text{hydrogen bromide} \rightarrow 1 - \text{bromobutane}$ (minor product)	• Learners may confuse hydrolysis reactions with hydration reactions since both reactions produce alcohol. • e.g. $\text{haloalkane} + \text{strong base (NaOH)} \rightarrow \text{alcohol} + \text{hydrogen halide.}$ (hydrolysis) • $\text{haloalkane} \xrightarrow[\text{conc.NaOH}]{\text{UV}} \text{alkene} + \text{hydrogen halide}$ (elimination)
What do you intend students to learn from this idea?	• The ester is formed during a reaction called esterification. • **Esterification** is a reaction of alcohol and carboxylic acid in the presence of sulfuric acid as a catalyst. • e.g. $\text{alcohol} + \text{carboxylic acid} \xrightarrow[\Delta H]{H_2SO_4} \text{ester} + \text{water}$ • **Reaction conditions:** Add a few drops of H_2SO_4. Heat in a water bath.	• Halogenation, hydrogenation, hydration, and hydrohalogenation are examples of addition reactions. • **Hydrohalogenation** – addition of hydrogen halide e.g. HCl, HBr, or HI to an alkene. No water must be present. Major products formed during this reaction. Haloalkane must be dissolved in a non-polar solvent. • **Halogenation** – addition of halogen e.g. Cl_2 or Br_2 to alkene. • **Hydration** – addition of excess H_2O in alkene and a small amount of dilute strong acid (e.g.H_3PO_4, or H_2SO_4). A major product is formed during this reaction. • **Hydrogenation**- the addition reaction of hydrogen to an alkene. • **Reaction condition**: alkene is dissolved in a non-polar solvent with a catalyst (Pt/Pd/Ni) in an H_2 atmosphere.	• Reactions of hydrogen halide (HCl/ HBr) with alcohols produce haloalkane and water. • Reactions of bases with haloalkanes during hydrolysis reaction produce alcohol and hydrogen halide. • **Hydrolysis** is a reaction of salt with water • The reaction between alkane and halide produces haloalkane and hydrogen halide.
Why is it important for students to know this idea?	• Esters are essential in the food industry because they have fruity smells.	• Addition reactions are helpful in the industry to produce polyethylene for the production of plastics.	• Hydrogen halide is a valuable intermediate for the manufacture of other substances.

	• Ester is also used in medicine to produce flavors in syrups and in the cosmetic industry to produce a fruity smell in lotions.	• Polypropylene is used for packaging. • Polyvinyl chloride for construction and plastic piping. • The hydrogenation reaction is also used in the preparation of margarine (a concept done in grade 9 natural sciences).	• e.g. hydrogen halide reacts with alcohols to produce haloalkane
What else you might know about this idea that you intend students not to know yet?	• The reaction of esters to form polyester.	• Addition reaction of polymers.	• The condensation reaction of polymers • The reaction is regarded as hydrolysis even though hydrolysis is the sub-reaction
What other factors influence the teaching of this idea?	• Learners associate alcohol with the ones found in taverns e.g. beer. • The knowledge of acids and bases in grade 11, especially the acid-base theories. • The learners know the structural formula for a functional group of alcohol and carboxylic acids from knowledge of homologous series.	• Definition of hydration and hydrolysis reaction because both reactions involve the presence of –OH. • The knowledge of homologous series, especially alkane. Knowledge of hydrogenation in grade 9 natural sciences for (margarine only) unsaturated fats.	• Learners might confuse hydrolysis and hydration reactions. • The knowledge of saturated organic compounds.
What do you consider easy or difficult about teaching this idea?	• Misconceptions during IUPAC naming and structural formulae of alcohols and carboxylic acids can lead to an incorrect ester. • It is difficult to explain that hydroxyl group (OH) is from a carboxylic and a bond with hydrogen atom (–H) is from an alcohol during esterification. Teachers need to use different colors when presenting this and further demonstrate it using models.	• Addition reactions involve many types of reactions with related reaction conditions which bring a lot of confusion to learners during lesson presentation. • For example: hydrohalogenation condition: no water must be present; the presence of water can produce alcohol. • Water contains stronger intermolecular forces than hydrogen halide	• In the case where one reactant is provided, learners may confuse substitution with elimination reactions. • The reaction condition of a dilute strong base during hydrolysis confuses learners with a concentrated strong base for dehydration reaction. • Hydrolysis uses ethanol dissolved in water but dehydration uses pure ethanol. E.g. $\text{alkane} \xrightarrow[\text{dil}]{\text{NaOH}} \text{alcohol} + \text{inorganic compound}$ • Learners may assume that for substitution reactions, there are two reactants and two products. • Learners may confuse reaction conditions since there is also a possibility of elimination reaction if a strong concentrated base is used. E.g. $\text{alkane} \xrightarrow[\text{conc}]{\text{NaOH}} \text{alkene} + H_2$
What representations would you use in your teaching strategy?	• Symbolic representations can be used to write balanced equations for esterification.	• Models or sweets (allsorts/marshmallows with toothpicks) can be used to represent the microscopic level of atoms.	• Symbolic representations will be used. E.g. HCl/HBr, $C(CH_3)_3OH$

	• Models can be used for microscopic representation. • The experiment can be done to represent the macroscopic level. Learners can smell the fruity smell of esters. • e.g. Ball and stick Models will be used for microscopic representation. To demonstrate the formation of ester, a simple experiment must be conducted to represent the process macroscopically. ***Ball and stick model*** *Clue for balls:* *Black- carbon* *Red- oxygen* *White-hydrogen*  +  =  +  ***Structural formulae:***  ***IUPAC names:*** $methanol + methanoic\ acid \rightarrow methyl\ methanoate + water$	• Symbols can be used to represent equations for different addition reactions. ***Ball and stick model*** *Clue for balls:* *Black- carbon* *Red- oxygen* *White- hydrogen*  +  =  ***Structural formulae:***  ***IUPAC names:*** $ethene + hydrogen = ethane$ ***Condensed structural formulae:*** $CH_2CH_2 + H_2 \rightarrow CH_3CH_3$	• Ball and stick Models can also be used to represent the microscopic level. ***Ball and stick model*** *Clue for balls:* *Black- carbon* *Red- oxygen* *White- hydrogen*  +  =  +  ***Structural formulae:***  ***IUPAC names:*** $2-methylpropan-2-ol + hydrogen\ chloride = 2-chloro-2-methylpropane + water$ ***Condensed structural formulae:*** $C(CH_3)_3OH + HCl \rightarrow C(CH_3)_3Cl + H_2O$

	Condensed structural formulae: $CH_3OH + HCOOH \rightarrow CH_3OOCH + H_2O$		
What effective teaching strategies would you use to teach this big idea?	**Demonstration:** • The teacher can demonstrate the formation of esters using for example ethanol and ethanoic acid. Learners can identify the characteristic smell. • Using the above example, a balanced chemical reaction can be represented in IUPAC names, condensed structural formula, and structural formula. For example: $ethanol + ethanoic\ acid \rightarrow ethyl\ ethanoate + water$ $CH_3CH_2OH\ +\ CH_3COOH$ $CH_3CH_2OCOCH_3 + H_2O$ **Use of models:** Learners can be given models to build compounds and re-arrange them to form products. ***Ball and stick model*** *Clue for balls: Black-carbon, red-oxygen White-hydrogen*  ***Structural formulae:***	**Demonstration:** • Models can be given to learners to build compounds and re-arrange them to form a product. **Hydrogenation**- the addition reaction of hydrogen to an alkene. Reaction condition: alkene is dissolved in a non-polar solvent with a catalyst ***Ball and stick model*** *Clue for balls: A black ball represents a carbon atom and, a white ball represents a hydrogen atom*  **Analogies:** Usage of symbols to draw structural formulas for addition reactions. ***Structural formulae:***  ***IUPAC names:***	**Probing questions:** Give examples of saturated organic compounds. What is meant by hydration reaction? **Analogies:** Substitution reaction occurs when saturated molecules react with other substances to produce saturated molecules. Examples of saturated molecules are alkanes, alcohols, and haloalkanes. The focus is on the Interconversion between haloalkanes and alcohol. **Examples: 1. Reaction of alkanes with halogens to produce haloalkane and hydrogen halide** propane + bromine = 2-bromopropane $\mathbf{CH_3CH_2CH_3 + Br_2 = CH_3CHBrCH_3 + HBr}$ **Reaction condition**: sunlight/ultraviolet light/heat and add halogen **2. Reaction of alcohol with hydrogen halide to produce haloalkane and water** ***Ball and stick model*** *Clue for balls: Black- carbon Red- oxygen White-hydrogen. Purple-sodium*  ***Structural formulae:***

	 ***IUPAC names:*** $methanol + methanoc\ acid \rightarrow methyl\ methanoate + water$ ***Condensed structural formulae:*** $CH_3OH + HCOOH \rightarrow CH_3OOCH + H_2O$	$ethene + hydrogen = ethane$ ***Condensed structural formulae:*** $CH_2CH_2 + H_2 \rightarrow CH_3CH_3$ **Reaction conditions:** Add Pt/Ni/Pd as a catalyst **Hydrohalogenation** – addition of hydrogen halide e.g. *HCl, HBr,* or *HI* to an alkene. No water must be present. Major products are formed during this reaction. Haloalkane must be dissolved in a non-polar solvent. **Halogenation** – addition of halogen e.g. Cl_2 or Br_2 to alkene. **Hydration** – addition of excess H_2O in alkene and a small amount of dilute strong acid (e.g. H_3P, or H_2SO_4). A major product is formed during this reaction. (Pt/Pd/Ni) in an H_2 atmosphere.	 ***IUPAC names:*** $2-methylpropan-2-ol + hydrogen\ chloride = 2-chloro-2-methylpropane + water$ ***Condensed structural formulae:*** $C(CH_3)_3OH + HCl \rightarrow C(CH_3)_3Cl + H_2O$ **Reaction condition:** Tertiary alcohols work best in this reaction. Primary and secondary alcohols react very slowly and at high temperatures. **3**. The reaction of haloalkanes with bases to form alcohols and salts is called hydrolysis  ***Structural formulae:***

			 ***IUPAC names:*** $2-methylpropan-2-ol+hydrogen\ chloride = 2-chloro-2-methylpropane+water$ ***Condensed structural formulae:*** $C(CH_3)_3OH+HCl \rightarrow C(CH_3)_3Cl+H_2O$ **Reaction conditions:** Add a strong base (NaOH/KOH) and heat
What questions would you consider important to ask in your teaching strategy?	• Teachers can probe questions on the importance of esters in industry. • Teachers can use the IUPAC name for reactions of alcohols and carboxylic acids and allow learners to give products and then present balanced chemical equations using a structural formula, condensed structural formula, or molecular formula. • The teacher can probe questions on reaction conditions for esterification.	• Teachers can use the IUPAC name for halogenation, hydration, hydrogenation, or hydrohalogenation, and allow learners to write products and then present balanced chemical equations using a structural formula, condensed structural formula, or molecular formula. • Teachers use flow diagrams and allow learners to predict types of addition reactions and write major or minor products that can be produced. • The teacher can probe questions on reaction conditions for types of addition reactions.	• In a given haloalkane/alcohol students can be asked to write a major product or minor product that can be produced during the substitution reaction. • In a given substitution reaction students can be asked to write down reaction conditions for that reaction. • In a given substitution reaction students can be asked to use a structural formula to write down a balanced reaction