Integrative knowledge building in blended instruction: An exploratory study of Organic Chemistry lessons

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ABSTRACT

Blended instruction has become a widely accepted teaching and learning method, however its potential to support integrative knowledge building particularly in science education remains underexplored. Although current blended learning models have shown promise in improving student learning, they often prioritise how technology can be integrated and the role of the learners in these contexts while relegating the role of teachers as well as knowledge structures and practices inherent within these contexts. Using Legitimation Code Theory (LCT), specifically the autonomy dimension which comprises of positional autonomy (PA) and relational autonomy (RA), this study explores how integrative knowledge building occurs in organic chemistry lessons delivered through both contact and asynchronous online sessions. The study argues that by establishing forms of knowledge structures and practices in each mode, it may be possible to enhance existing blended learning models or introduce new perspectives on their pedagogical structure. The study adopted a qualitative case study research approach within the interpretivist paradigm. The primary data was collected through direct observations for contact sessions and pre-recorded video observations for online sessions. In addition, document analysis and interviews were used to supplement the primary data. A total of eight teachers within a Technical Sciences cluster teaching grade 12 participated in the study.

The study found that, although teachers in both modalities were able to build knowledge that is integrative, online lessons offered greater opportunities for supporting this integration. In addition, it was found that integrative knowledge building was informed by the unique affordances of contact and online modes as teachers navigated across these modes through context responsive pedagogical strategies. The study identified distinct knowledge practices that either enabled or constrained knowledge building and further highlighted the importance of the role of teachers and the need for teachers to expand their knowledge base to support integrative knowledge building. These insights informed the development of the Blended Learning Pedagogical Integration Model (BLPIM), which provides a framework for supporting integrative knowledge building across blended environments, particularly in science education. Implications for practice include the need for curriculum developers, teacher educators, and institutional leaders to design blended learning frameworks that support integration of knowledge building strategies into both curricula and teacher training programs. These frameworks should give special attention to the relationship between content, context and pedagogy. The study further recommends the implementation of professional development programs to equip teachers with explicit strategies for intentional knowledge integration to meet pedagogical and conceptual demands of blended instruction.

Key Words*:* Integrative knowledge building, Blended instruction, Knowledge practices, Autonomy codes, Legitimation Code Theory, Online learning, Contact learning.

DECLARATION

I, Angeline Duma, student number **1143754** declare that this research study is my own work. It has not been submitted before for any other degree or examination in any other university. All the work taken directly from other works has been cited accordingly and the full list of references has been provided. I fully understand that the University of the Witwatersrand will take disciplinary action against me if evidence suggests that this is not my own unaided work or that I failed to acknowledge the sources of the ideas or words in my writing.

University of the Witwatersrand, 30 June 2025

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DEDICATION

To my Lord God,

All glory and thanks to You for granting me the strength, wisdom, and perseverance to complete this study.

To my daughter Nolwandle Duma,

You are the light of my life and the reason I strive to be better. This thesis is a reflection of perseverance, sacrifice, hope and it is for you! May it always remind you that no dream is too big, no goal too distant. You can become anything you choose to be. The world is yours to shape.

To Orlando Secondary School,

A place that nurtured my early dreams and laid the foundation for this journey. This thesis is dedicated to you and to every learner walking your halls. Let it stand as proof that success can emerge from anywhere, even from the heart of the township. To the upcoming generation: believe in your potential, aim high, and know that your future is not defined by your beginning.

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ABBREVIATIONS AND ACRONYMS

DBE	Department of Basic Education
DoE	Department of Education
NSC	National Senior Certificate
CAPS	Curriculum Assessment Policy Statements
SACE	South African Council of Education
PTSs	Professional Teaching Standards
STEM	Science Technology Engineering and Mathematics
COVID 19	Corona Virus
Col	Community of Inquiry
SAMR	Substitution Augmentation Moderation and Redefinition
CABLS	Complex Adaptive Blended Learning System
LCT	Legitimation Code Theory
PA	Positional Autonomy
RA	Relational autonomy
IKB	Integrative Knowledge Building

CHAPTER 1: INTRODUCTION TO THE STUDY

1.1. Introduction

The past decade has witnessed significant transformations in teaching strategies, primarily driven by the increasing integration of technology in education and the unprecedented impact of the coronavirus disease (COVID-19) pandemic. The outbreak necessitated the closure of educational institutions while compelling the continuation of the education process through alternative means. As a strategic measure to prepare for unforeseen circumstances and capitalise on the accelerated adoption of technology in education, an increasing number of institutions have recognised the advantages of integrating multiple teaching methodologies. This approach facilitates student learning through traditional instructional methods alongside online learning resources and activities; a format commonly referred to as blended instruction. Blended instruction typically combines face-to-face and online instruction (Hrastinski, 2019). Face-to-face instruction denotes in-person educational activities wherein students and instructors convene in a classroom or designated area for direct engagement and teaching (Chisadza et al., 2021). Online learning on the other hand refers to a digital educational setting that operates without the physical presence of an instructor or students and is not limited by time or location (Kedia & Mishra, 2023).

Blended instruction transcends the augmentation of conventional, in-person training through technology; it is not simply a modification of delivery medium or a technology-enhanced supplement to existing face-to-face education. Instead, it is perceived as a transformative pedagogical approach (Garrison, 2017). The distribution of the time allocated in blending lessons depends on the instructor. For example, Arbaugh (2014) indicated that a blended course combines online learning with face-to-face class activities in an intentional pedagogically valuable way where somewhere between 20% and 79% of content and activities are delivered online. Regardless of how it is structured, blended instruction may improve student engagement and provide more flexible learning opportunities (Ashraf et al, 2021). The method of teaching and learning qualifies to be called blended learning only if it involves a meaningful and purposeful combination of two or more learning systems (Jowsey et al., 2020). Blended learning is an effective learning approach in the modern day, according to Thahir et al. (2023).

The growing interest in integrating blended instruction into modern and future teaching methods requires a thorough evaluation of the existing governing paradigms. These models must sufficiently elucidate how teachers interact with knowledge and effectively demonstrate the knowledge practices intrinsic to blended learning environments. In these environments, teaching models must address the complex role of educators in facilitating and building knowledge within such contexts.

Among factors influencing pedagogy in any learning situation, including blended contexts, is integrative knowledge building. Integrative Knowledge Building (IKB) uses systematic approaches to promote learning through the integration of knowledge from various disciplines, viewpoints, and practical experiences. Maton and Howard (2020) define integrative knowledge building as the incorporation of various knowledge practices or sources of knowledge. Integrative knowledge building generally fosters collaborative knowledge production, analytical reasoning, and problem-solving within educational environments. Blackie et al. (2022) contend that integrative knowledge building is fundamental to ongoing learning and a crucial element in tackling complex, real-world challenges. It focuses on how teachers amalgamate diverse forms of information and knowledge practices within their lessons. Various sources of information, encompassing everyday experiences and insights derived from disciplines beyond the subject being taught, can be utilised during instruction to convey knowledge of a specific topic.

This study positions integrative knowledge building as the pedagogical core through which blended instruction can be conceptualised and enacted. By examining contact and online sessions as interrelated spaces of knowledge construction, the research seeks to identify how science teachers integrate multiple knowledge practices across modes. The insights from these analyses are expected to inform the development of a blended learning model that provides teachers with an explicit and adaptable framework for fostering integrative knowledge building, whether teaching online, face-to-face, or through a blend of both. Investigating integrative knowledge building in educational settings is crucial, as educators are tasked with delivering a designated curriculum while simultaneously utilising students' prior knowledge or interdisciplinary learning to equip them with valuable cognitive resources, whether in online or face-to-face formats.

The instruction and comprehension of chemistry, encompassing organic chemistry, have emerged as significant concerns for educators and researchers (Omwirhiren & Ubanwa, 2016;

Uce & Ceyhan, 2019). The challenges inherent in chemistry education necessitate a solution that enhances student performance. Organic chemistry is a branch of chemistry focused on the scientific study of the structure, characteristics, and reactivity of organic molecules and materials, which consist of carbon atoms in various forms (Clayden et al., 2012). Adu-Gyamfi and Asaki (2022) attribute the abstract nature of organic chemistry to learners' difficulties in comprehending its macroscopic domain (e.g., the physical identification of organic compounds), sub-microscopic domain (e.g., the understanding of atoms and bonds constituting an organic molecule), and symbolic domain (e.g., the formulation and representation of chemical equations for organic molecules). Individuals with minimal or no prior knowledge of organic chemistry encounter challenges in comprehending a combination of these dimensions or even a single dimension (O'Dwyer & Childs, 2017).

Consequently, educators must address the obstacles faced by students (Stojanoyska et al., 2020), as the calibre of organic chemistry instruction in schools is contingent upon the proficiency of the chemistry teachers. Although blended learning has been widely adopted in education, several studies indicate that its pedagogical potential, particularly in subject-specific and school-level contexts, remains underexplored (Janse van Rensburg & Oguttu, 2022; Chakawodza et al., 2024). In many cases, existing research focuses on technological implementation or student engagement rather than on how blended learning can be designed to enhance conceptual understanding and teaching effectiveness (Bruijn-Smolders & Prinsen, 2024). This study, therefore, explores how integrative knowledge building occurs across contact and online sessions as interdependent components of blended instruction, using grade 12 organic chemistry in technical sciences as an illustration. In doing so, it seeks to provide empirical and conceptual insights that inform the development of a pedagogical model for blended learning, grounded in the realities of classroom practice.

1.2. Background of the study

In the evolution of education, blended instruction emerged as a transformative force well before the pandemic (Ashraf et al., 2021), yet it took the unprecedented challenges brought about by COVID-19 to accelerate its widespread acceptance. The emergence of the pandemic was unforeseen, and the potential it held to disrupt the education system was not fully recognised. Subsequently, it became increasingly evident that the pandemic had the capacity to completely disrupt the educational landscape. This was observed when educational systems around the world had to close for an undefined period (Reddy & Naidoo, 2022). According to Salmi

(2020), the shutdown of campus-based instruction affected around 20,000 institutions and 200 million students globally in higher education.

The global pandemic brought about a new normal to which we all had to adapt and evolve, and in the process, the education sector learned important lessons that cannot be overlooked. The sudden shift from in-person to online sessions led to concerns in the basic education sector regarding the implementation of online instruction (Zubane et al., 2022), due to insufficient preparation time for both educators and students to address these obstacles. Challenges comprised insufficient teacher training and limited resources in educational institutions and home environments (Huber and Helm, 2020; Zhang et al., 2020). While certain schools successfully transitioned to online learning, it is important to note that numerous educators in South African schools lacked adequate formal training to facilitate blended learning or to implement online learning effectively (Jantjies, 2020). Private and affluent schools adapted their instruction by integrating contact sessions with online formats for teaching and learning (Maree, 2022). In contrast, many schools in disadvantaged communities did not experience similar modifications (Mahlangu, 2021 in Maree, 2022). This resulted in disparities in the quality of education received, as all learners in the country undertake common examinations and are evaluated using uniform standards.

The closure of educational systems prompted the critical realisation that schools cannot remain shuttered indefinitely. Consequently, discussions surrounding online learning began to dominate educational corridors (Bao, 2020; Dhawan, 2020), ultimately raising hope for educational systems that had previously relied heavily on contact teaching (Daniel, 2020). Discussions around online learning in response to the prolonged closure of educational institutions underscored the necessity for adaptable educational strategies. As the pandemic subsided, the discourse around online learning did not dissipate; instead, it expanded into a broader conversation about blended instruction (Süner-Pla-Cerdà et al, 2023; Mmakala & Maphalala, 2023; Singh et al., 2021). The necessity of the pandemic to prompt recognition of the importance of blended instruction raises critical questions about the readiness and adaptability of educational systems. Had there been proactive recognition and integration of blended instruction prior to COVID-19, the educational landscape might have been better equipped to navigate unforeseen challenges. As noted by Raghunathan et al. (2022), the pandemic serves as a stark reminder of the need for proactive measures in education to foster resilience and adaptability. Considering this, the question that emerges is: Will it take another pandemic or specific disruptions for the education sector to equip educators and students with the skills needed to support online instruction?

The pandemic surely provided enough lessons for change in the educational landscape. As argued by Zubane et al. (2022), in nations like South Africa, where numerous schools are situated in underprivileged neighbourhoods, the Department of Basic Education (DBE) has been prompted to anticipate probable interruptions in the future and to guarantee that these disruptions minimally affect learners. Embracing blended learning as a fundamental approach to education post-pandemic is highly commendable, as it ensures that educational institutions are adequately prepared to navigate any future disruptions (Singh et al., 2021; Olawuni & Mavuso, 2022). Beyond technological efficiency preparation, educators ought to be pedagogically equipped to work with knowledge in online and contact sessions. This means understanding knowledge practices that foster effective learning in blended contexts.

The absence of in-person instruction posed significant obstacles across all disciplines; however, it was the practical subjects such as technical sciences that encountered the most pronounced difficulties (Hong et al., 2021). Science subjects generally encompass practical activities wherein students independently conduct experiments and derive conclusions. The advancement of scientific process knowledge and skills improves students' ability to understand scientific facts and concepts, as well as to discover new information through experimental activities, thereby enhancing their academic performance in educational settings (Gizaw & Sota, 2023). The COVID-19 lockdown profoundly affected science education by transitioning instruction from conventional classrooms to digital platforms, resulting in challenges including diminished hands-on experimentation, restricted student engagement, and inequities in technological access (Tang, 2023; Onyema et al., 2020). The absence of laboratory work hindered learners' practical skills, impeding the development of a profound conceptual knowledge of scientific ideas (Affouneh et al., 2020).

Moreover, educators encountered challenges in assimilating digital tools and sustaining interactive learning settings (Mishra et al., 2020). In a South African case, organic chemistry represents a significant portion of the examinable content, accounting for 32% of the chemistry paper, as outlined in the Curriculum and Assessment Policy Statement (CAPS) document that offers instructional guidance (DBE, 2014). Learners’ inability to perform well in this topic, resulting from teachers’ limited competence or insufficiently developed teaching strategies, may negatively affect their overall performance in chemistry, potentially leading to poor results or failure.

1.3. Rationale

The educational landscape has significantly transformed because of the COVID-19 epidemic. The pandemic served as a catalyst for transformation (Mavuru & Ramaila, 2022), necessitating that educational systems capitalise on the insights gained from this experience. Mbhiza (2021) observes that the global pandemic has tested the conventional standards of teaching and learning in school. A growing cohort of scholars, such as Van der Westhuizen and Hlatshwayo (2023), Mahlaba and Sekano (2023), and Singh et al. (2021), endorse blended education as a prospective pedagogical approach. While advocating for blended learning is commendable, it is equally crucial for educational systems to transcend mere enthusiasm for change. Blended instruction, integrating traditional in-person teaching with online learning, has emerged as a transformative method in contemporary education, enhancing flexibility, engagement, and learning efficacy. Current studies on blended learning have shown its capacity to enhance student engagement, information acquisition, and problem-solving skills. Advocating for blended learning alone is insufficient; genuine transformation necessitates an assessment of the pedagogical foundations of mixed instruction.

Comprehending knowledge structures and practices influence academic performance for students (Maton & Howard, 2021). Investigations into knowledge building enhance practices by broadening the educators' knowledge base (Rusznyak et al., 2021), this enables a collective of educators to embrace shared frameworks applicable in particular settings. Moreover, when the information underpinning practice is apparent, educators easily identify the rationale for their decision-making processes. Learners achieve a more profound comprehension of the content when instructional approaches facilitate linkages between many forms of knowledge including their experiences. Organic chemistry is known for being complex and requiring students to connect different ideas (O'Dwyer & Childs, 2017). This makes it a good subject to explore how blended learning can help students build and use knowledge in a connected way so that they can solve problems and understand the subject better.

Although research has underscored the significance of instructional strategies and technology in mixed environments, there are still deficiencies in comprehending how these components might be enhanced to promote interdisciplinary thinking and application. This is apparent in the restricted investigation of how blended education explicitly facilitates integrated knowledge construction, especially in STEM subjects such as organic chemistry. This study seeks to fill these gaps by examining the function of blended education in facilitating integrated knowledge building during the teaching of organic chemistry lessons. This thesis aims to explain how integrated learning environments can be designed to enhance students' ability to synthesise and apply concept which is a critical skill necessary for success in chemistry and related fields.

1.4. Problem statement

Organic chemistry offered at schools is foundational yet challenging for learners taking technical science as it requires them to understand complex concepts and apply them to real-world problems. Adding to challenges in learner performance in this topic is a large percentage afforded the topic compared to other topics (DBE, 2014), which implies that less proficiency in this topic can compromise learner's performance in the chemistry paper. The nature of the content in organic chemistry makes it difficult for learners to grasp when taught solely through traditional face-to-face instruction, without the support of online instruction that can offer unique pedagogies and strategies to support learning, including the use of specific digital resources. Traditional teaching methods often fail to help students synthesise and apply concepts across different contexts; a key aspect of integrative knowledge building that blended instruction is well positioned to enhance. Similarly, online instruction without carefully designed pedagogical strategies, such as reflective activities that guide learner understanding, can also hinder effective knowledge construction. Therefore, leveraging the strengths of both face-to-face and online modes can create a blended learning environment that effectively promotes integrative knowledge building as it combines the interactive opportunities of traditional instruction with the flexibility and diverse pedagogical tools of online learning (Garrison, 2008; Graham, 2013). In the context of organic chemistry, this approach can help learners synthesise complex concepts and apply them across different contexts, addressing the limitations of relying solely on either mode.

While existing models for blended instruction provide frameworks that emphasise student engagement, use of newly developed technologies and technical skills required to facilitate blended learning, they do not address all aspects of teaching for every topic. For challenging subjects like organic chemistry, it is necessary to look beyond technology and learner-centered strategies to how teachers work with knowledge in these settings. As argued by Rusznyak et al. (2021) teachers can recognise the foundation for decision-making in practices when the knowledge that underlies and informs it is made explicit. This highlights the importance of approaches that integrate teaching practices with content specific learning.

Knowledge practices can be recognised when educators within given contexts are entrusted with the crucial role of building knowledge in the lessons they teach. This is a key feature for academic achievement (Maton & Howard, 2018). Current research on blended learning has largely focused on general outcomes such as student performance or satisfaction, with limited attention to how blended environments can support the synthesis and application of knowledge across contexts. The potential of blended learning to support integrative knowledge building in organic chemistry remains underexplored. In particular, there is little evidence on how specific instructional strategies within blended settings can effectively address the unique challenges of organic chemistry, such as integrating complex concepts and developing problem-solving skills.

1.5. Purpose of the study

The purpose of this exploratory study is to investigate how blended instruction supports integrative knowledge building in organic chemistry lessons. Specifically, this research aims to examine knowledge structuring patterns and practices that enhance students' ability to synthesise and apply concepts across contexts. By establishing forms of knowledge practices in both contact and online sessions, it may be possible to enhance existing blended learning models or introduce new perspectives on their structure. Central to this argument is the idea that educational institutions dedicated to blended instruction must critically evaluate current models while simultaneously considering how these models can be adapted to prioritise knowledge building as a core component of teachers' role in these contexts.

Framing education as centred around knowledge building is essential, and Scardamalia and Bereiter's seminal work in 1999 underscores this, advocating for the transformation of schools into knowledge-building institutions. This insight emphasises the enduring significance of prioritising knowledge building regardless of the instructional format, whether in online or contact sessions. By addressing gaps in the existing literature, this study aims to offer actionable insights for educators on how to design blended learning environments that effectively promote deeper conceptual understanding and application in STEM education.

1.5.1. Aims and objectives of the study

The main aim of this study is to explore how integrative knowledge building takes place in lessons taught through contact and online sessions when teaching organic chemistry.

The objectives are:

- To establish the target knowledge that is prescribed by the curriculum in the teaching of organic chemistry and establish if teachers comply to the curriculum document.
- To identify shifts in knowledge structuring patterns when teaching organic chemistry through contact and online sessions.
- To examine how autonomy pathways in contact and online sessions promote integrative knowledge building.
- To explore the knowledge practices that enable teachers to facilitate integrative knowledge building in blended learning environments.
- To develop a blended learning model that can effectively guide teachers in integrating knowledge.

1.5.2. Research questions

Given the aim and the objectives that guide this study, the research questions to be answered in this study are:

Main research question:

How does integrative knowledge building take place in lessons taught through contact and online sessions?

Secondary research questions:

i. How do teachers adhere to the curriculum target knowledge of organic chemistry?
ii. What shift in knowledge structuring patterns are observed when teaching organic chemistry through contact and online sessions?
iii. How can autonomy pathways in online and contact sessions promote the development of integrative knowledge building?
iv. What practices in blended learning environments can promote integrative knowledge building?

v. How can a model for integrative knowledge-building through blended instruction and other supportive frameworks be developed?

The secondary research questions (i-iv) focus on specific aspects of integrative knowledge building. Research question (v) is positioned as an emergent question, with its answers drawn from the findings of research questions (i– iv) and the insights gained throughout the research process, rather than being pre-determined. This ensures that the model developed is grounded in the study's empirical data and the observed teaching practices.

1.6. Significance of the study

Comprehending knowledge-building patterns and instructional practices is essential for learners' academic success. Framing blended instruction to facilitate knowledge building aids in guiding pedagogical transformations and knowledge patterns that enhance knowledge development in blended environments. In this study, this encompasses knowledge from organic chemistry, other scientific subjects, various disciplines, and everyday experiences. The variations in instructional modalities result in differing practices that promote integrated knowledge building, which may also exhibit certain similarities. Nonetheless, current models of integrated knowledge construction and blended education lack clarity regarding the knowledge practices inherent in teaching and learning processes. This study asserts that knowledge-building frameworks should provide educators with pedagogical practices that adopt a holistic approach. The study's conclusions aim to aid in the development of a pedagogical integrative model that clearly emphasises the knowledge practices teachers can employ throughout instruction. The methodology of examining each instructional medium individually aims to enhance understanding of integrative knowledge-building techniques, hence fostering research applicable to blended contexts, with findings relevant to both face-to-face and online modalities.

1.7. Delimitations

While this study does generalise its findings to all schools, it does not include any other STEM subjects and only examines organic chemistry lessons. This limits the conclusions about other topics taught in technical sciences or broader STEM discipline. Furthermore, the study was done with only eight participants located in one district and one province, whereas the generalised findings could imply many schools offering the subject.

1.8. Chapter outline of the thesis

Chapter 1 introduces the study by situating it within the broader educational and pedagogical context, outlining the research problem, rationale, purpose, and significance. It presents the aim, objectives, and research questions, highlighting the theoretical and conceptual underpinnings of integrative knowledge building in blended instruction. This chapter also provides an overview of the study's scope and delimitations. **Chapter 2** presents a review of the literature that informs this thesis which is important to contextualise the focus of the study and identify gaps that justify the study. **Chapter 3** provides a detailed account of the theoretical framework guiding this study. Legitimation Code Theory (LCT), with a specific focus on autonomy codes, is examined as the guiding framework. This chapter discusses how and why the theory aligns with this study. **Chapter 4** outlines the research design and methodologies. It details the processes followed in data generation and analysis. The chapter further explains how reliability and validity were ensured. The chapter concludes by giving a detailed account of ethical considerations relevant to the study. **Chapter 5** presents the results of the study. It reports on curriculum target knowledge, knowledge structuring patterns, autonomy pathways, and teacher practices in both contact and online sessions. The chapter highlights how integrative knowledge building occurs in blended instruction and synthesises these findings to develop a blended instruction pedagogical model that supports teaching and learning in organic chemistry. **Chapter 6** outlines the summary of research findings and discussions by positioning the findings within the theoretical underpinnings that informed this study and finally **Chapter 7** concludes the study and provides implications for further research and recommendations particularly in science classrooms.

1.9. Chapter summary

This chapter provided the introduction of the study and outlined the background, rationale, problem statement which guided the purpose of the study and research questions, significance of the study, delimitations and the chapter outline. The next chapter presents the bodies of literature that informed this study.

CHAPTER 2: LITERATURE REVIEW

2.1. Introduction

Chapter 2 reviews the key bodies of literature that inform this study. The first part of this review unpacks literature that outlines the progression of knowledge in terms of its attributes and uses in education. As such concepts such as knowledge and its development, knowledge transfer, types of knowledge building, knowledge building in the teaching and learning of science as well as the importance of teachers assuming the role of knowledge builders in their classrooms are explored. The second part of the review examines the concept of blended instruction as well as the common models. Furthermore, concepts such as affordances and constraints of online and contact sessions and the evolving nature of blended learning post-pandemic are examined. The final part reviews literature on the teaching and learning of organic chemistry, which serves as the context for exploring integrative knowledge building across both online and contact settings in this study.

2.2. Knowledge and its development

Knowledge is the consequence of deliberate acts of production, which are accomplished through constructing a system of ideas from simple ideas (Scardamalia & Bereiter, 2014). Zagzebski (2017), views knowledge as a valuable state that explains the relationship between a conscious subject and a part of reality with which the knower is directly or indirectly associated. This implies that knowledge is an intentional or conscious activity in which individuals engage and involves cognitive and emotional processes (Bosilani et al., 2012; Maton & Howard, 2020). While the cognitive aspects of knowing are important, it is also necessary to comprehend the various qualities, attributes, and forms that knowledge takes (Maton & Howard, 2020). This points to the idea that knowledge is not just about acquiring facts but also about understanding its different dimensions and how it manifests in various contexts. Knowledge is validated, agreed-on, codified and published set of concepts that form the basis of a given discipline at any point in time (Scardamalia & Bereiter, 2006). According to Parent et al. (2014), knowledge can be perceived as experiences; contextual understanding, value-added information, or insights derived from the cognitive frameworks of individuals or groups, which must be autonomously managed and exists in the forms of tacit or explicit knowledge.

Various meanings of knowledge can include knowledge-in-development in each *discipline*, and knowledge in-development in *school* contexts (Scardamalia & Bereiter, 2006). Knowledge in-development in a discipline describes the processes by which new knowledge in each discipline is developed over time: that is, the experimentation, collaboration, argumentation, negotiation, and debate that takes place between the people who are the field's experts, as they "construct" new knowledge, using the procedures and protocols of that discipline, with one another. Successfully participating in knowledge-in-development requires skills and dispositions over and above personal mastery of the discipline's key concepts, skills, and dispositions. These skills and dispositions usually develop informally, alongside conceptual knowledge, as individuals are inducted into a particular expert context. In other words, knowledge in- development cultivates the knower gaze, clearly stipulating what counts being an expert in the science field. Clarence and Mckenna (2017) emphasise the importance of teachers being aware of the types of knowledge and skills learners should possess when learning a subject. This implies that the teacher must be explicit about how they are moulding the learners into the tasks of a scientist. Developing learners into knowers of the subject provides them with the skills they need to succeed in that subject.

Knowledge in- development in *school* contexts does not refer to disciplinary knowledge, but rather to the collective "constructs" made by groups of students as they work together. It denotes the processes students experience together as they do this work (Bereiter & Scardamalia, 2014). Students need to move beyond viewing knowledge as fixed and an unquestionable truth but instead understand it as something that evolves through creativity and continual improvement.. Although students may generate new discipline knowledge, it is crucial to cultivate their intellectual growth through active engagement in its development. In doing so, they become active constructors of knowledge in their learning process. The amalgamation of activities such as knowledge creation, transmission, application, storage, identification, and acquisition is perceived as more advantageous to the organisation than the execution of each individual action (Parent et al., 2014).

2.3. Knowledge transfer

To ensure an organisation remains competitive in global competition, knowledge must be communicated expeditiously (Alshahrani, 2021). Within this study, educational institutions are regarded as organisational entities, and the term organisation is used accordingly. Knowledge transfer encompasses the transmission of knowledge between individuals and involves the interaction of a source and a recipient (Weiwei et al., 2020). Abinbuhaybeha (2023) asserts that knowledge transfer encompasses knowledge circulation, updating, experience, and maintenance among personnel inside the organisation, emphasising social linkages. It transpires when individuals within the organisation exchange knowledge, skills, recommendations, and ideas relevant to the organisation. The heightened significance of knowledge transfer necessitates that organisations implement effective mechanisms for this transfer (Asrar-ul-Haq & Anwar, 2016). Gera (2012) posits that the transfer of knowledge involves recognising existing information, acquiring it, and subsequently utilising it to generate new concepts or enhance old ones thus optimising the process for efficiency, quality, or safety beyond its previous state.

Knowledge transfer protocols enable adherence to organisational policies and facilitate the enhancement of understanding and learning among individuals within the organisation. By acknowledging its significance, organisations can get a competitive edge in the global landscape (Son et al., 2020). Knowledge transfer activities are regarded as personal initiatives where most on the process needs to be done by individual by following the organization setup to establish effective knowledge transfer (Hassan et al., 2017). Efficient knowledge transfer enhances comprehension within organisations and diminishes ambiguity among stakeholders. The basis of knowledge building is knowledge itself; nevertheless, the process requires active engagement, transformation, and integration, rather than mere accumulation.

2.4. Knowledge building

While knowledge development focuses on how new ideas are constructed and refined through creative and collaborative processes, knowledge transfer concerns how these ideas are shared, organised, and mobilised within and across contexts. In essence, the continual development of knowledge has little value unless it is effectively communicated and transferred, allowing it to inform practice, innovation, and further learning. Knowledge building is premised on the idea that each student is a legitimate contributor in the creation of authentic and creative knowledge. Bereiter and Scardamalia (2003) define knowledge building as creative, sustained, collaborative working with ideas, with the aim of *improving* those ideas. It is the creation and continuous enhancement of ideas of value to a community based on the premise that when individuals collaborate, they contribute more to society. (Scardamalia & Bereiter, 2006) posit that knowledge-building is intentional, collaborative, cognitive activity, the purpose of which is to build collective capacity, while at the same time also contributing to the wider social good. Knowledge building aims to engage students directly in the active processes by which knowledge in the world is advanced. Vokatis and Zhang (2016) added that knowledge building is a dynamic, social activity system in which students connect with a variety of people and ideas to develop their collective knowledge. As a results, knowledge building assumes that student communities can do much more and produce knowledge that will enable them to progress (Scardamalia & Bereiter, 2014). This requires effective collaborative learner centred strategies in teaching. In this process, knowledge in the classroom emerges as a collective and distributed phenomenon rather than residing in any single student's mind (Scardamalia & Bereiter, 2014). It involves guiding students into this process at an early, pre-expert stage through apprenticeship. According to Scardamalia, (2002), knowledge building includes: epistemic agency, original ideas and authentic problems. It also involves continuous idea improvement, shared responsibility for community knowledge, knowledge-building discourse, and meaningful usage of authoritative sources, all of which guide knowledge-building in teaching contexts. Improvements of ideas that emerge during knowledge building are made available for further work by others and thus contribute to a context beyond the individuals involved.

2.5. Types of Knowledge Building

Knowledge building can take various forms, depending on the context, purpose, and level of engagement. Each type plays a distinct role in advancing understanding of knowledge building in teaching and learning processes (Dittrich, 2025). The variety of knowledge building forms are outlined below:

2.5.1. Conceptual knowledge building

Conceptual knowledge in general describes understanding how all pieces of information are linked together in a network (Rittle-Johnson & Schneider, 2015; Baroody et al., 2007; Miller & Hudson, 2007). VanScoy (2019) adds that conceptual knowledge is an explicit or implicit understanding of the principles that govern a domain and of the interrelations between pieces of knowledge in a domain. This implies an understanding of the definitions, rules and principles in an area of knowledge. The interrelations between pieces of knowledge or a network can occur between underlying principles that govern a domain (Rittle-Johnson et al., 2016). For example, in science classrooms the connection can be visualised when previously learned scientific ideas or concepts are connected or between concepts previously learned. According to National Academic Press (2018), specific knowledge and skills that are not incorporated into coherent conceptual organizations tend to exist as isolated facts or pieces of information. These are often difficult to remember, recognise in context, or apply in a productive way. At the same time, a rich foundation of specific knowledge animates abstract concepts and provides accessible, meaningful instantiations of important relations and patterns. In practice, this implies a reflection of student's ability to reason and comprehend concepts, operations, and relations between ideas that may be helpful in solving non-routine problems (Al- Mutawah et al., 2019).

Conceptual knowledge and understanding are an important goal in learning generally, but particularly relevant in science education because such understanding is required to make sense of scientific phenomena (Phanphech et al., 2019) which are often complex and abstract. Conceptual understanding requires students to organise facts and ideas into meaningful concepts in science. This organisation helps students form webs that can help them make connections between the science concepts and their experiences. Therefore, a process of developing, refining, and integrating deep, interconnected understanding of concepts rather than just accumulating facts is described through conceptual knowledge building.

In terms of process, conceptual knowledge building implies moving beyond surface-level knowledge to establish meaningful relationships between ideas thus allowing learners to apply and extend their understanding in different contexts. Mills (2016) reiterated that students who understand a subject conceptually do not depend on memorisation approach rather they formulate ideas while learning. In other words, they can ask questions based on their understanding, transform and reconstruct their knowledge structures. Science teaching should be focused on conceptual understanding to improve students' ability to reinforce connections and organise knowledge (Mills, 2016). While conceptual knowledge centres on the understanding of abstract theories, principles, and operations (Yee, 2019), procedural knowledge encompasses the skills and methods that enable learners to apply and deepen that understanding (Findell et al., 2001).

2.5.2. Procedural knowledge building

According to VanScoy (2019) and Saks et al. (2021) procedural knowledge is knowledge of specific strategies, actions and individual skills that are used to accomplish tasks and solve problems. Hussein (2022) identified two aspects relating to procedural knowledge which are procedural knowledge and knowledge of rules. Procedural knowledge is seen as knowledge of formal languages and knowledge of rules used to complete tasks in a specific domain. The above definitions highlight the practical and action-oriented nature of knowledge which is often referred be several scholars as "knowing how" (Saks et al., 2021; Gottlieb, 2015) rather than just theoretical understanding. It can be deduced that procedural knowledge focuses not just on knowing the principles and theories of the domain but knowing how to use that knowledge to accomplish tasks, solve problems or follow systematic procedures within a particular domain. The emphasis on procedural knowledge as practical and action-oriented highlights its role in interactive learning processes. Schiefelbein and McGinn (2017) noted that procedural knowledge alone is not sufficient to support the acquisition of learning skills, it should be coupled with conceptual knowledge of the learning process. This implies that combining the different forms of knowledge building can improve overall understanding of the concepts which is the primary goal of education. In practice, procedural knowledge is often developed through collaboration between students and teachers or among students themselves. Procedural knowledge is not only an individual cognitive process but also a social one, occurring within interactive and collaborative spaces (Le et al., 2018; Ralston et al., 2017)

In STEM education, there is substantial evidence supporting the effectiveness of active learning in enhancing student engagement and understanding (Freeman et al., 2014; Arthurs & Kreager, 2017; Dou et al., 2018). In these disciplines procedural knowledge is best acquired through hands-on, participatory learning experiences that reinforce the application of concepts in real-world contexts. Arnold et al. (2017) argues that activating students' procedural understanding during scientific inquiry can improve students' scientific thinking. Therefore, the teaching of organic chemistry requires the incorporation of procedural knowledge. In organic chemistry it includes student's ability to draw molecular and structural formulas, using organic chemistry rules to name compounds, identifying general formulae's and conducting experiments for reaction (DBE, 2011; DBE, 2014).

2.5.3. Collaborative knowledge building

Collaborative knowledge building stems from the idea that schools should function as communities where knowledge is collectively constructed rather than individually acquired (Scardamalia & Bereiter, 1994). Gilbert and Driscoll (2002) emphasise that the primary goal of collaborative knowledge building spaces is to develop a shared knowledge base within the community while enhancing learners' problem-solving expertise. However, as Zheng and Zheng (2021) point out, collaborative knowledge building does not occur spontaneously, it requires deliberate guidance from teachers. This suggests that successful collaborative knowledge building processes depend on the teacher's active role in adopting specific knowledge building strategies. Hmelo-Silver and Barrows (2008) argue that the kinds of questions asked, and the statements posed during instruction enable knowledge building discourse. Furthermore, in collaborative knowledge building students are active participants in identifying knowledge problems and collectively improving their ideas. Chan et al. (2012) report that an analysis of collaborative knowledge building dynamics indicated that students showed deeper engagement and inquiry over time. Considering the complex and abstract nature of science concepts (Molnár et al., 2023; Millar, 1991) students unpacking knowledge together can indeed act as a scaffold of scientific knowledge (Chan et al., 2012). At the heart of collaborative knowledge building is the collective improvement of ideas (Cao, 2021). This suggests that collaborative knowledge building can refine and transform scientific understanding over time as instruction progresses. Coupled with reflective practices, learning indeed becomes transformational.

2.5.4. Reflective knowledge building

Reflective practice refers to deliberate thinking about actions that has already taken place and deliberate examination of classroom procedures, attitudes and interactions (Mathew, 2012). Reflective knowledge building can be understood as a process that requires the engagement of two interrelated yet distinct entities: reflective teaching and reflective learning. The former focuses on practices which are aimed to continually improve teachers' efficacy and abilities (Machost & Stains, 2023). This implies that reflective practice provides a means for teachers to improve their practice to effectively meet the learning needs of their students. In carrying out their duties, science teachers need to have the ability to practice reflection, not only be able to think reflectively but also act reflectively (Babutta et al., 2024). This requires intentionality about specific actions carried out during instruction for sustainable science teaching. As argued by Mathew (2012) teaching is purposeful interaction intended to promote learning as it involves teacher and learner engaging in joint purposeful activity. Honest reflections and evaluations of teachers' pedagogies are required by way of questioning what they do and rethinking what they would do to give scope for self-improvement and innovative teaching practices (Mathew, 2012).

Literature has revealed two major modes of reflection; reflection in action and reflection on action (Schon, 1983; Agoro, 2013; Ogunleye, 2015; Cattaneo & Motta, 2021). Reflection-in-action refers to active evaluation of thoughts, actions and practices during action (Iqbal, 2017) whereas reflection on action denotes the kind of reflection that occurs after the action; thus, it is retrospective in nature (Satariyan & Reynolds, 2016). Reflection in and on action are effective at improving students' achievement in Chemistry when compared with the conventional instruction (Ogunleye, 2015). While reflective practice focus on the importance of students acknowledges to revisit what they have learned for improvement and for in-depth learning (Chang, 2019), their reflection requires deliberate strategies and activities facilitated by teachers. This has the potential to assist students in their learning because many of them may not be used to reflecting on their learning in a structured manner. Cultivating these skills collectively fosters reflective knowledge-building practices within the classroom. This can lead to transformative knowledge which goes beyond simple reflection to involve a deeper re-evaluation of beliefs and assumptions, leading to a shift in perspective and action (Taylor, 2017).

2.5.5. Transformative knowledge building

Generally, transformative learning refers to a perspective transformation or change in worldview (Baumgartner, 2019). In the educational context, it is based on promoting change, where educators challenge learners to critically question and assess the integrity of their deeply held assumptions about how they relate to the world around them (Eschenbacher, 2020). This implies a learning that goes beyond sharing or accumulating facts to a process of refining ideas such that students alter their ways of understanding and thinking. Urmetzer et al. (2020) points that transformative learning can be understood as one important step towards attaining transformative knowledge. Thus, the processes that result in students attaining transformative knowledge can be understood as transformative knowledge building. In this sense, transformative knowledge building extends beyond the acquisition of information to encompass critical reflection, dialogue, and re-evaluation of assumptions. It requires learners to actively interrogate their own perspectives and reconstruct understanding through engagement with diverse ideas and experiences.

Mezirow et al. (2000) contends that content, process and premise questions can serve as a catalyst for transformative learning. Content questions play an essential role in making learners aware of their assumption or beliefs in relation to the content (Cranton, 2016). For example, content questions can include prior knowledge. Process questions on the other hand ensures that learners establish a source for their assumptions while premise reflection questions reveal the underlying core beliefs using 'why' (Cranton, 2016). Such questions require learners to trace back their reasoning thus propelling them to recognise the sources and processes behind their knowledge. Building transformative knowledge therefore requires elements such as critical reflection, perspective change, and the reorganisation of prior knowledge into new, more inclusive structures (Cranton, 2016; Dirkx, 2006). Within this study, transformative knowledge building is viewed as an essential dimension of integrative knowledge building, as it captures the cognitive and affective shifts that occur when teachers and learners integrate diverse forms of knowledge across contexts and modalities.

2.5.6. Cultural knowledge building

The term culture refers to combination of values, customs, beliefs and practices that make up the lifestyle of a specific group (Öngören, 2018). Richter (1972) defines cultural knowledge as any set of ideas, prevailing in each culture or subculture, which provides away of organising information about the world or about any aspect of it. Öngören (2018) adds that it is knowledge shared by the social groups that the individual belongs to. Cultural knowledge building, therefore, involves constructing and sharing knowledge that is shaped by social, linguistic, and cultural contexts.

Building knowledge that is cultural therefore requires a culturally responsive pedagogy in educational contexts. According to Caingcoy (2023) a culturally responsive pedagogy is an educational approach that recognises the diverse backgrounds and experiences of learners and seeks to create inclusive and engaging learning environments. As argued by Johansson (2009) integrating cultural backgrounds and knowledge into school practice enhances professional awareness and highlights the relevance of cultural diversity in teaching and learning. In a similar vein (Gay, 2018) argues that a culturally responsive teaching involves recognising and valuing the cultural diversity of students and using this understanding to tailor instruction and engage students more effectively. Villegas and Lucas (2007) add that a culturally responsive approach to teaching is meant to promote engagement, enrichment, and achievement of all students by embracing a wealth of diversity, identifying and nurturing students' cultural strengths, and validating students lived experiences and their place in the world. A central role of culturally responsive teaching is to help students bridge their existing cultural knowledge with new disciplinary learning. Teachers, therefore, play an active role in connecting students' lived experiences to academic content and creating learning spaces where cultural perspectives are legitimised as part of collective knowledge building (Villegas & Lucas, 2007).

Caingcoy (2023) asserts that teachers must possess the knowledge and skills to address the' specific needs of culturally diverse students in their classrooms. For cultural knowledge building to be effective in teaching situations, teachers should first possess specific cultural competences. These are skills or abilities required to successfully teach students from different cultures (Moule, 2012). Sue (2001) adds that cultural competence in education involves understanding, respecting, and effectively responding to the cultural differences that students bring to the classroom. Cultural knowledge building, therefore, supports integrative knowledge building by fostering learning environments where multiple knowledge forms whether scientific, experiential, and cultural can intersect. In blended learning contexts, this integration enables teachers to connect online and contact-based experiences to students' cultural realities, enriching understanding and engagement. Cultural knowledge building is thus based on the premise that to teach subject matter in meaningful ways and engage students in learning, teachers need to know about their student's lived experiences and have strategies in place to embrace diverse cultural experiences. While cultural knowledge building can help foster engagement and create a sense of belong, Cooc and Kim (2021) noted that teachers' backgrounds are different from learners causing barriers in implementation. This is particularly true in the South African contexts where classrooms are usually multicultural, multilinguistic and multiracial.

2.5.7. Technological knowledge building

In the educational landscape, technology play a crucial role in supporting knowledge-building communities and communities of practice (Hoadley, & Kilner, 2005). However, technology is improving every time, leading to the use of new technologies in teaching and learning. As a result, teaching with technology is complicated by challenges newer technologies present to teachers (Koehler & Mishra, 2009). Laurillard (2012) points out that in the 21st century teachers must cope with everchanging technological environments. This implies adapting and embracing strategies and tools that may foster technological knowledge building. Technological knowledge describes teachers' knowledge of, and ability to use, various technologies, technological tools, and associated resources (Kurt, 2018). Laurillard (2012) noted that technological knowledge building focuses on how educators can design learning experiences using technology to foster knowledge construction in lessons, therefore teachers and learners should possess technological capabilities for technological knowledge to be constructed in various ways. Integration efforts should be creatively designed or structured for subject matter ideas in specific classroom contexts (Koehler & Mishra, 2009).

2.5.8. Integrative knowledge building

The preceding forms of knowledge building represent interrelated pathways through which learners and teachers construct understanding. However, integrative knowledge building encompasses the synthesis of these diverse processes, illustrating how knowledge from different sources and practices is brought together within and across learning contexts. The general term "integration" describes the act or process of uniting different aspects; integrative knowledge building is thus coiled from this general understanding. Maton and Howard (2020) define integrative knowledge building as knowledge that integrates various knowledge practices. Simply put, integrative knowledge building is concerned with how knowledge from various sources can be brought together during instruction. According to Maton and Howard (2018), the ability to bring knowledge together is critical to academic achievement. Maton and Howard (2018) identified three barriers to comprehending integrative knowledge building: knowledge blindness, essentialism, and segmental modelling.

Knowledge blindness occurs whenever there is a limited ability to see knowledge. Maton (2014) contends that to see knowledge, it is crucial to build a sociology of knowledge that operates with an understanding of knowledge as something real, with distinct types of knowledge varied in structure, attributes, and effects. According to Maton and Howard (2018), studies on knowledge frequently focus on cognitive and emotional processes of knowing. Knowledge, according to Maton (2014), is neither cognitive nor social, and interpreting knowledge primarily as inner mental processes or focusing entirely on knowledge as social power leads to knowledge blindness. Maton and Chen (2020) further argue that knowledge blindness values analysis of ways of knowing and overlooks knowledge as an object of study.

According to Maton and Howard (2018), knowledge is a study in and of itself; knowledge comes in many various forms, and those forms of knowledge have implications for how successfully that knowledge can be combined with other forms. Integrative knowledge, as a result, overcomes knowledge blindness by bringing together actors with open and inquisitive minds (Maton & Howard, 2018). This means that actors such as teachers can relate any form of knowledge. These forms of knowledge can range from complex, abstract, or insulated knowledge (Maton & Howard, 2018).

Furthermore, integrative knowledge building allows for the dismantling of preconceived categories in favour of concepts that explore the diversified, changeable, and contextual nature of knowledge practices without falling victim to relativistic paralysis (Maton & Howard, 2018). Integrative knowledge building, according to Maton and Howard (2018), moves away from essentialism, which considers the dimensions that knowledge practices take as self-evident, undisputed, and unchangeable. According to Sahin (2018), essentialism is an educational philosophy that holds that things share natural and essential characteristics that are inherent, innate, and unchanging. In a related manner to Maton and Howard (2018), Sahin (2018) further asserts that essentialism can lead to undesirable practices in real life. When knowledge is considered unchangeable and innate, practitioners find it difficult to see knowledge as taking numerous forms that are significant in practices.

Maton and Howard (2018) further argue that segmental models, which struggle to incorporate real-world data, cause barriers to understanding integrative knowledge building. When new concepts or skills are learned alongside existing knowledge rather than being built on top of it, segmental knowledge building emerges (Maton, 2009). Walton and Rusznyak (2019) similarly argue that ideas that do not integrate existing knowledge exemplify segmental knowledge building. Learners may know multiple facts or procedures but struggle to see how they connect. If new concepts are not linked to prior knowledge, students might struggle to apply or transfer their understanding across different contexts (Maton, 2013). Maton and Howard (2018) emphasise that concepts that uncover structural principles within practices, while providing clear indications of the criteria over time, are necessary to explore integrative knowledge building. Understanding shifts in knowledge structuring patterns helps overcome issues of knowledge blindness, essentialism, and segmental models (Maton & Howard, 2018).

Beyond these theoretical considerations, integrative knowledge building is also crucial in the context of high school science education. Many students struggle to apply their knowledge in new situations because instruction often prioritises rote learning and algorithmic problem-solving over deeper conceptual understanding (OECD, 2016). Research in science education indicates that teaching for conceptual change is essential, as rote learning seldom leads to understanding science concepts (Nadelson et al, 2018; Duit et al, 2013). Similarly, Cairns and Areepattamannil (2022) reported that teacher-directed explanations that explicitly link scientific ideas to students' everyday experiences are positively associated with higher science achievement. This highlights the importance of conceptual teaching focus rather than than purely procedural teaching. In the same vein, the National Academies of Sciences emphasise that conceptual understanding is strengthened when learners connect new ideas to prior experiences and construct coherent conceptual frameworks (National Academies, 2018). International assessments such as the Programme for International Student Assessment (PISA) have also documented this challenge, showing that students frequently perform well on memorisation-based tasks but face difficulties in applying knowledge to unfamiliar problems (OECD,2016). This reflects the segmental nature of learning described, where knowledge is acquired in isolated units without sufficient integration across concepts.

According to Kostøl and Remmen (2022), connecting scientific content to students' everyday experiences through context-based approaches enhances the perceived relevance and meaning of science learning. Similarly, research on authenticity in science education demonstrates that when learners engage with real-world contexts, they develop a deeper sense of purpose and are more likely to sustain engagement (Schriebl et al, 2023). Kervinen et al. (2020) complements this by highlighting that linking science instruction to students' lived experiences and cultural practices bridges the gap between abstract concepts and everyday understanding. In the context of this study, this would imply an intentional use of strategies that allow learners to apply organic chemistry in their daily lives. Doing so would promote meaningful engagement and deeper conceptual understanding of abstract science concepts.

A key tension exists between the targeted nature of high school curricula and the goal of integrative knowledge building. Teachers are expected to align closely with syllabus demands, which ensures content coverage but can limit opportunities for students to connect ideas across topics and disciplines (OECD, 2016). Addressing this tension does not imply resisting the syllabus; rather, it calls for curriculum policies and classroom practices that encourage interdisciplinary approaches, linking new concepts with prior knowledge and promoting a deeper understanding of scientific principles (Maton & Howard, 2018).

Practical strategies for fostering integrative knowledge building include curriculum reforms that encourage interdisciplinary learning (Stevenson et al, 2024), professional development that equips teachers with integrative teaching strategies (Philander and Botha, 2021; Pretorius et al, 2014), and assessment innovations that evaluate students' ability to apply knowledge rather than merely recall information. By creating learning environments that value knowledge as an object of study and emphasise connections across contexts, educators can help students overcome knowledge blindness, essentialism, and segmental learning (Maton & Chen, 2020), hereby equipping them with the skills and understanding needed to navigate complex scientific and real-world problems.

2.6. Knowledge building in science teaching and learning

Science instructions, employing the knowledge building approach, is typically executed through discovery learning, inquiry-based methods, or problem-based project work. Knowledge building shares the aim of science which include the development of a community's reliable and comprehensive theories (Chen et al., 2019). It involves students engaging in collaborative, inquiry-based activities to create and refine knowledge, fostering deeper understanding and critical thinking skills, similar to how scientists work. Science involves being innovative, which requires students to be actively involved in their learning. This supports what Paavola and Hakkarainen (2005) indicated that knowledge building values innovation of ideas and theories that arise through engagements from prior conceptions. This entails involving students fully in the processes of knowledge construction from early stages (Scardamalia & Bereiter, 2006). Knowledge building involves not just the construction of knowledge but also the creation of public knowledge that benefits the community. This approach applies to various fields, including education, where students collaboratively engage in developing theories, designing experiments, and refining ideas through sustained discourse. Knowledge building represents a complex systems account of new knowledge (Gabor & Kauffman, 2016). Different types of knowledge building contribute to deep learning, innovation, and problem-solving across fields. Knowledge building is useful, not just for students, but for teacher development.

2.7. Teacher's importance as knowledge builders

Scardamalia and Bereiter (1999) argued persuasively for the transformation of schools into knowledge-building institutions. Building on this argument, Tan (2010) argues that teachers should first be knowledge builders to turn schools into knowledge-building organisations. This requires teachers to participate in collaborative improvement of ideas related to theories and practice of teaching and learning. Such engagements will consequently aid in the improvement of student's academic performance. As highlighted through the South African Council for Education (SACE) and the Professional Teaching Standards (PTSs), knowledge building is at the core of the teachers' work (SACE Final Draft, 2018). Vokatis and Zhang's (2016) highlights features such as professional knowledge building as one of the identities of the teachers. According to them teachers occasionally experiment with new teaching ideas to improve knowledge building over time. Being a knowledge builder is seen as a professional identity (Vokatis & Zhang, 2016) which calls for professional development which is increasingly collaborative, data-driven, and facilitated, all with a focus on classroom practice (Barber & Mourshed, 2009). In the same fashion, DuFour et al. (2020) suggests that teachers ought to participate in professional learning communities and where they can observe lessons by colleagues, to reflect and discuss authentic classroom practices (Tan, 2010). In support of professional learning communities Hartnell-Young (2003) suggests that teachers will become more involved in shaping their roles if they have space to reflect on current practice and to become more familiar with the frameworks, tools and resources available to them.

Since teaching is a cognitive activity, it is important for teachers to understand and monitor the development of their teaching habits (Öztürk, 2021) through practices they adopt. Ouyang et al. (2021) adds that teachers need to work as knowledge builders instead of simply reproducing "best practices" in teaching. The implementation of knowledge building in the classroom requires teachers to design an educational environment that promotes active learning opportunities. Ma and Scardamalia (2022) add that such environments should enable students to share, question, debate ideas, and develop new skills with the purpose of constructing and refining their knowledge about authentic problems. This implies that the role of the teacher as the knowledge builder cannot be divorced from the role of learners in constructing knowledge. As Howard-Jones (2019) noted, building knowledge requires a two-way communication between the teacher and students where the teacher guides knowledge construction and consolidates learning through application, practice and reflection. A study by Gutiérrez-

Braojos et al. (2024) reported that students valued teachers' explanations and scaffolding processes on specific topics as tools for supporting knowledge building. This implies that teachers need to be deliberate about teaching habits and practices they adopt if knowledge building is the goal. Additionally, rich explanations are because of rich understanding of the subject matter.

2.8. Conceptual foundations and interpretations of blended instruction

The terms 'blended instruction,' 'blended teaching or learning,' are used interchangeably and refer to the same concept in this study. For many years, researchers have debated the meaning of blended learning, yet the definition of blended learning remains ambiguous as the concept constantly evolves. As a result, according to Hrastinki (2019) the clarity of blended learning depends on the context of studies. Pratama et al. (2018) defines blended learning as a combination of several learning strategies and delivery modalities that will maximise the users' learning experience. Although he indicates that in blended instruction, delivery methods are combined, there is no mention of the specific delivery methods or strategies of teaching and learning. Janse van Rensburg and Oguttu (2022) on the other hand, defines blended learning as learning that combines online and face-to-face instruction. This definition clarifies the modalities involved, highlighting the combination of online and traditional classroom experiences.

Thus, blended learning is an intentional blend of these two methods of instruction; this definition moves us closer to the conceptualised meaning of blended learning for this study. Husamah (2018) describes blended learning as a combination of e-learning and multimedia technology. The emphasis is on e-learning and multimedia, which suggests online approaches but makes no mention of face-to-face learning. Kumar et al. (2021) defines blended learning as a mixture of traditional face-to-face classroom and e- learning experiences. Bartolomé Pina (2004) and Hrastinski (2019) have also defined blended learning as a type of instruction that blends face-to-face and online instruction to purposefully employ pedagogical activities, technologies, and strategies that integrate both face-to-face and online learning for the benefit of students. By highlighting that blended instruction is a thoughtful approach instead of just a simple mix of different modalities, this description clearly conveys the complex nature of teaching and learning. This thorough comprehension demonstrates the intentional and planned aspects of blended learning. Additionally, blended instruction includes the deliberate integration of online and face-to-face activities, with both activities linked with and reinforcing one another (Janse van Rensburg & Oguttu, 2022; Norberg, 2017; Oliver & Trigwell, 2005; Van Valkenburg et al., 2020). A synthesis of these perspectives positions blended instruction not merely as a combination of modalities but as an evolving pedagogical approach that enables the integration of knowledge practices across contexts. Within this study, blended instruction is examined as a process through which insights from online and contact sessions collectively inform the development of a pedagogical integration model aimed at supporting teachers in enacting integrative knowledge building.

A consolidated various definitions of blended learning leads to a common understanding that it can be defined as a teaching or learning approach that uses information technology to integrate two types of instruction: online and direct learning (Rohartati, 2023). Direct learning in this case refers to the traditional classroom instruction of face-to-face teaching and learning, which is understood as contact sessions in this study. With regards to how teaching methods are blended, Bruck et al. (2022) expand on the description of blended learning to include a mixture of synchronous and asynchronous instruction, as well as practice-based and classroom-based instructional settings. Synchronous online learning is defined as live and real-time facilitated instruction that is scheduled (Shahabadi & Uplane, 2015) using a variety of platforms. On the other hand, asynchronous online learning refers to a computer-based learning modality in which geographically separated learners interact on a given subject irrespective of time and location (Carr, 2012). Asynchronous instructional settings give students easy access to resources such as PowerPoint presentations, handouts, articles, and audio/video lectures (Perveen, 2016). Blended instruction, as coiled in this study, is therefore understood not only as a strategic combination of selected online learning environments through asynchronous online modes with contact learning experiences, but also as a pedagogical pathway towards integrative knowledge building. In this way, it reflects both a teaching method and a model-building process that connects insights from each mode of delivery into a unified blended learning framework.

2.9. Exploring Blended Instruction Models

Khan (2022) identified three common blended learning models which are widely accepted and used in education. These models are the Complex Adaptive Blended Learning System (CABLS), Community of Inquiry Framework (Col), and the Substitution Augmentation Moderation and Redefinition (SAMR) model. Each of these frameworks offers valuable insights into specific dimensions of blended instruction such as systemic relationships, community interaction, or technological integration. However, their perspectives differ in scope and emphasis, leaving open opportunities for further conceptual exploration of teaching practices within blended contexts.

2.9.1. The Complex Adaptive Learning System (CABLS) framework

Becher Araujo Moraes (2023) defines the CABLS model as an advanced framework for understanding and improving blended learning implementation. Wang et al. (2015) developed this model, which emphasises the link between six fundamental components: learner, teacher, content, technology, learning support, and institution. According to Wang et al. (2015), the elements within the model influence each other, resulting in a learning system that is adaptable and responsive to the requirements of blended learning. The CABLS model's core feature is that the learner is at the centre, and all other components are influenced by the learner's role in this complex system (Khan, 2022). The learner evolves across the sub-components, shifting identities between researcher, collaborator, and practitioner (as shown in Figure 1). This learner-centred emphasis highlights the adaptive nature of blended learning environments, where students play an active role in shaping their experiences. While the model highlights the learner as a key element, it offers limited elaboration on how teachers' work with knowledge. It is not clear how the construction, transformation and the connection of knowledge interacts with these components in blended contexts. Based on the CABLS, the teacher interacts with the content and serves as a moderator, facilitator, advisor, and guide in the learning process (Becher Araujo Moraes, 2023). This characterisation highlights the importance of teacher guidance but leaves open the question of how teachers' knowledge practices evolve alongside learners in complex adaptive systems.

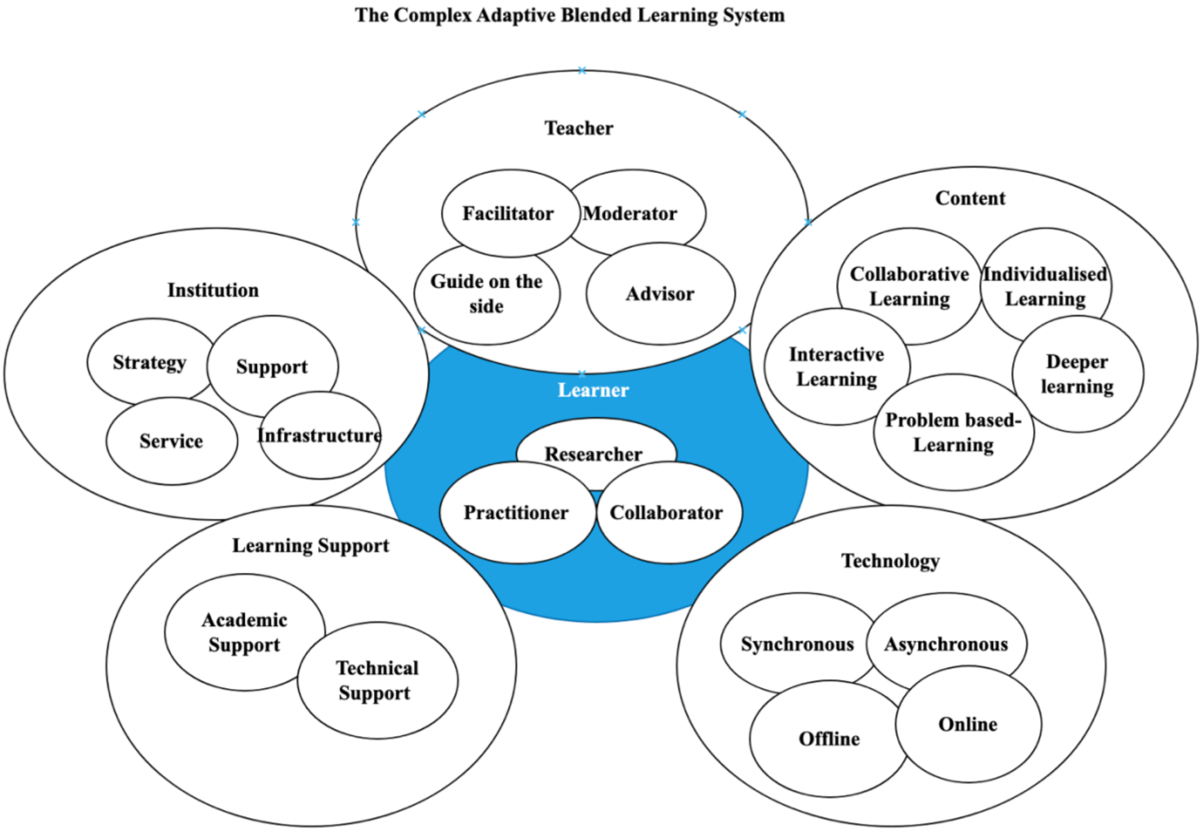


Figure 1: The CABLS framework (Wang et al. 2015)

Although other components such as technology, institutions, and learning support play a fundamental role in blended learning contexts, a more explicit articulation of how teachers engage with disciplinary knowledge and structure content could deepen understanding of the teacher's epistemic role in this model. The CABLS model is however successful in highlighting strategies such as deep, interactive, collaborative, problem based and individualised learning (Wang et al., 2015) which are key in assisting learners to build knowledge in science classrooms. Even so, the model focuses on cognitive aspects of learning rather than the various attributes, patterns or structures that knowledge takes. As argued by Maton (2014) focusing only on the cognitive aspects of learning leads to what was previously described as knowledge blindness. Thus, CABLS provides a robust systems-level view of blended learning but may benefit from integration with frameworks that make visible the structuring of knowledge practices and the teacher's epistemic agency.

2.9.2. The Community of Inquiry (Col)

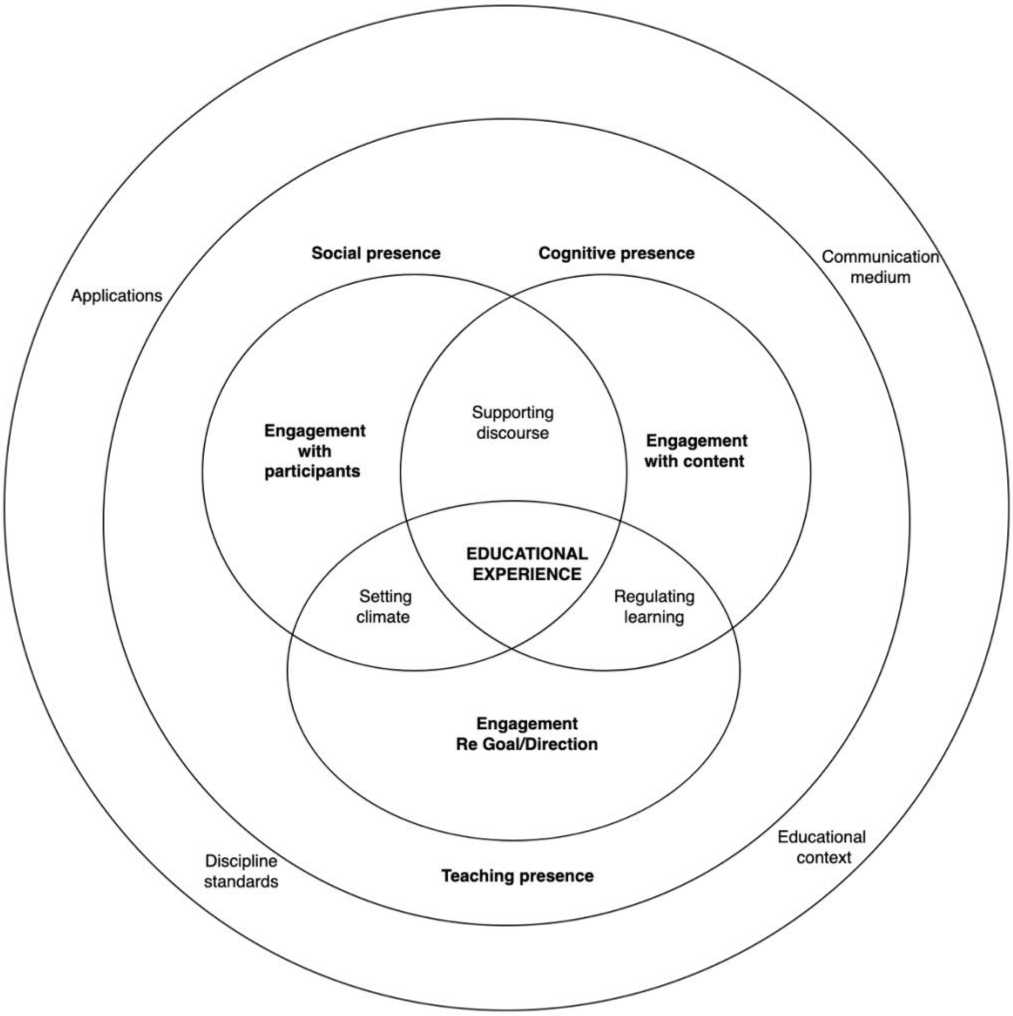


Figure 2: Community of Inquiry (Col) model (Adopted from Khan, 2022)

The Community of Inquiry (CoI) model, shown in Figure 2, represents a blended learning framework that identifies dynamic communities with cognitive, teaching, and social presence (Garth-James & Hollis, 2014). CoI is a model that aims to provide adaptive, collaborative, and engaging learning experiences through both process and content. As such, the Col framework identifies instructional activities based on theory and practice to facilitate inquiry learning that is guided for learners (Cleveland-Innes, 2019). Inquiry based learning as emphasised by the Col framework allows for the construction of scientific knowledge (Urdanivia Alarcon et al., 2023). Becher Araujo Moraes (2023) reports that the Col framework has received a lot of attention in education due to its ability to create communities in blended instruction. This allows for collaborative knowledge building which is necessary in science teaching.

Within this framework, cognitive presence refers to "the degree to which learners construct meaning through continuous reflection and dialogue in the inquiry learning community" (Zhang et al., 2020, p. 225). According to Garrison (2007), cognitive presence is classified into the following categories: triggering events, exploration, integration, and resolution. Garrison (2007) adds that information interchange, relating perspectives, and applying new ideas are key indicators of cognitive presence. Social presence, on the other hand, is "the ability to create a learning environment and atmosphere that enables learners to communicate in a friendly and supportive environment and demonstrate true social and emotional expression capabilities" (Zhang et al., 2020, p. 226). Finally, teaching presence refers to the "designing, promoting, and guiding learners' cognitive processes and social communication to achieve meaningful and valuable learning goals" (Zhang et al., 2020, p. 226). The strength of CoI lies in its holistic view of how teaching, social, and cognitive presences intersect to enable meaningful inquiry. However, while the model foregrounds collaboration and facilitation, it does not explicitly account for how teachers' disciplinary knowledge and pedagogical reasoning inform these presences. In this regard, the CoI model offers a valuable foundation for understanding interactional processes in blended learning but requires complementary perspectives to unpack how teachers mediate and transform knowledge within these interactions.

2.9.3. SAMR Model

The Substitution, Augmentation, Modification, and Redefinition Model (SAMR) (as shown in figure 3 below) is a widely used framework for discussing the innovative use of technology to transform learning (Nair & Chuan, 2021). Hamilton et al. (2016) state that the model's design is an instrument that allows teachers to monitor the use of technology during instruction. The model comprises four stages: Substitution, Augmentation, Modification, and Redefinition. Hamilton et al. (2016) state that the model allows teachers to progress from low to high degrees of technology integration. The SAMR model contributes a practical and hierarchical structure for understanding how digital tools can enhance or transform teaching and learning tasks. However, while it offers valuable guidance on levels of technology integration, it gives limited insight into the epistemological dimension of teaching, specifically how teachers' knowledge practices evolve through technology-mediated instruction. As argued by Hamilton et al. (2016), teaching and learning are dynamic processes rather than products of technological substitutions. Thus, the SAMR model is best viewed as a complementary lens that can inform, but not fully explain, the complexity of knowledge operations in blended instruction.

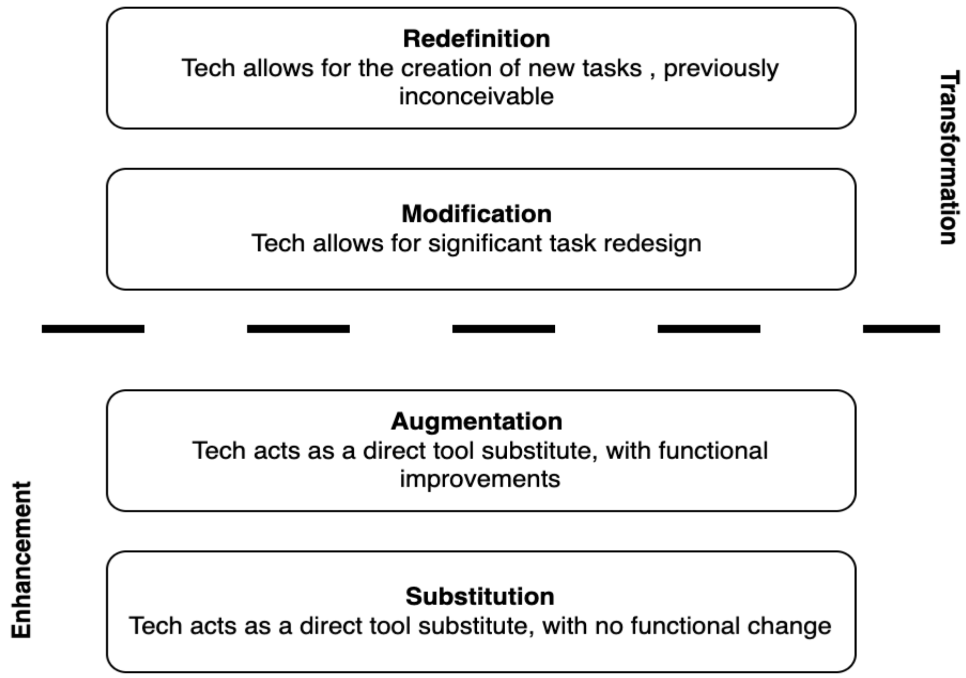


Figure 3:The SAMR Model (adopted from Puentedura, 2020)

The four stages of the model breakdown into two subgroups known as the enhancement and transformation stages (Hilton, 2016). Substitution and augmentation form part of the enhancement stage, while modification and redefinition form part of the transformation stage (see figure 3 below). In other words, the enhancement stage falls under the lower levels of the model while the transformation stage forms part of the higher level. The substitution stage, which represents the lowest level of technology integration is characterised by the replacement of traditional tools or activities (Khan, 2022). At the substitution level, the mode of instruction will be changed from manual to digital and there is no significant change in how the computers are being used (Khan, 2022; Lubega & Paul, 2014). A typical example is when learners use a computer to fill out a simple worksheet on organic chemistry questions. This is the most basic approach to using technology within science classrooms. Another example would be when the teacher replaces the overhead projector with PowerPoint presentations for increased functionality such as adding videos or hyperlinks for instruction (Bicalho et al., 2023).

Similarly, the augmentation level resembles the lowest functionality of technology, but there is a significant increase in function as compared to substitution. Hamilton et al. (2016) state that at the augmentation level, technology is exchanged, and the function of the task or tool positively changes in some way. As an illustration, the teacher can use websites and blog posts to deliver content that is current or unavailable in the school library's resources (Bicalho et al., 2023). By incorporating technology that might otherwise make the teaching experience different or lacking in some way, both substitution and augmentation enhance the quality of science instruction. On the other hand, the modification level transforms teaching as the technology is used to redesign learning tasks (Romrell et al., 2014). According to Bicalho et al. (2023), this stage necessitates a transition in teacher approaches to instruction in relation to the planned task. An example includes a situation where teachers use technology to redesign science activities that allow for deeper understanding and collaboration, such as online discussions, online conferences, and digital portfolios.

The final and highest level is the redefinition stage, where technology allows for the creation of tasks that could not have been done without the use of technology (Romrell et al., 2014; Bicalho et al., 2023). Pedagogical strategies used at this stage are carefully planned, as the main goal is for tasks to be completely redefined or transformed. An example includes giving learners a task that requires them to create videos of a particular topic as a form of assessment. Additionally, in science, teachers can plan to use simulations or virtual reality tools for interaction and more personalised learning experiences.

The SAMR model has been widely criticised for its lack of theoretical foundations and empirical evidence (Bicalho et al., 2023; Blundell et al., 2022). One criticism useful to this study is made by Blundell et al. (2022), who contend that the SAMR places emphasis on the technology used to complete tasks, thus making teaching and learning a product. Teaching and learning are dynamic processes that cannot be reduced to what technology can help achieve. As argued by Hamilton et al. (2016), teaching and learning is a process. Moreover, it is worth noting that the role of the teacher is reduced to technological pedagogical skills that can be used to enhance or transform teaching and learning. Additionally, the model focuses on building technological knowledge which is a tool for professional development (Sailer, 2021) rather than a pre-requisite for learning scientific concepts. Such an understanding reveals little about the complexities of the teaching and learning processes (Livingston, 2017). The SAMR does not explain how the technologies used connect to how teachers work with knowledge or the knowledge practices inherent when this model is adopted.

All three models discussed provide a basic understanding of models governing blended learning. However, none of them claim to provide a complete theoretical account of teaching and learning processes in blended environments. Khan (2022) contends that these models provide a platform for teachers to evaluate their creativity or manage e-resources suitable for blended learning. It is critical to comprehend the connections that exist between the technology, the content, and the teacher because doing so will reveal knowledge practices or structures that are unique to blended learning settings. In this study, these frameworks are not critiqued for their limitations but are used as conceptual entry points that highlight the need for a deeper understanding of teachers' epistemic roles and the structuring of knowledge practices within blended environments. To extend this understanding, Legitimation Code Theory (LCT) is drawn upon to make visible the underlying organising principles that shape integrative knowledge building across online and contact sessions.

2.10. Affordances and constraints of online and contact sessions as constituents of blended instruction

The preceding section made it clear that the key components of blended instruction are online and contact sessions. This section intends to provide insight into existing debates on online and contact sessions. This review is useful for understanding the constraints and affordances of these modes, which will help identify factors that may potentially hinder the success of blended instruction. Singh and Thurman (2019, p. 302) define online learning first as "learning experienced through the internet/online computers in a synchronous classroom where students interact with instructors and other students and are not dependent on their physical location for participating in this online learning experience", and secondly as "learning experienced through the internet in an asynchronous environment where students engage with instructors and fellow students at a time of their convenience and do not need to be co-present online or in physical space." These two definitions clearly reveal the distinction between the two online learning methods described in the previous subsection: asynchronous and synchronous.

The main difference between these two types of online methods synchronous and asynchronous teaching and learning, according to Rigo and Mikuš (2021), is the time in which teaching and learning occur. As indicated by Rigo and Mikuš (2021), synchronous learning occurs in real time, and participants engage in defined virtual spaces at a specified time, whereas asynchronous learning is based on students' schedules and does not occur in real time. Another distinction, which was highlighted by Simonson, et al. (2019) is that in asynchronous learning, students can access academic materials at a later stage. This study focuses on the asynchronous aspect of online learning, thus the affordances and constraints to be looked at will be centred on that. In contrast to online learning is face-to-face instruction, which Bušelić, (2012) describes as a common method of teaching in which students and teachers meet in person for a certain period in a defined location. The definition of face-to-face instruction as described by the preceding authors describes contact sessions as coiled in this study. Thus, the terms face-to-face and contact sessions means the same aspect in the context of this study.

A survey of the literature shows several advantages of online teaching and learning. Flexibility in terms of time and place has been highlighted by several scholars as a crucial and advantageous (my emphasis) aspect of online learning (see Wright, 2017; Serttaş & Kasabalı, 2020; Croxton, 2014). Likewise, Farajollahi and Zarifsanaee (2012) argue that online instruction is a significantly better environment for students than face to face instruction since learning may take place anywhere at any time. This is especially important in the context of South Africa where many students use public transport and have to wake up as early as 4am in the morning if they are to catch an 8am face-to-face lecture. Even for those who use their own cars, traffic congestion is always an issue. Farajollahi and Zarifsanaee (2012) further argue that online learning prepares students for a variety of educational goals, such as independent learning, self-directed learning, and self- assessment with increased flexibility. However, contrary to Farajollahi and Zarifsanaee (2012) is Costado Dios and Piñero Charlo (2021) who found out that in face-to-face instruction, students depend on teachers' explanations reducing students' sense of independence.

Bušelić (2012) also contends that online learning is flexible since learners can participate and engage with the learning materials at their own pace. This is supported by Hasifah (2020), who pointed out that online learning allows students to decide how much time they spend on a topic, the content they learn, and the direction of their learning. He adds that students have the option of revisiting difficult topics until they are confident in their comprehension. While the opinion that students' have a sense of autonomy in online settings is viewed as advantageous, it problematic that students can decide on the content they learn in online settings. This is because teacher-directed content should be the educational goal, as it is essential for helping students meet curriculum objectives and ensuring a comprehensive and high-quality education. Therefore, in both online and face-to-face instruction, the role of the teacher as a pedagogical expert should remain central. Asynchronous online learning allows students to gain access to multimedia resources such as videos, readings and interactive tools (Means et al., 2009) which they can interact with at the own convenience such that content is viewed repeatedly and reflected upon (Hrastinski, 2008). The flexibility of this teaching method allows learners to process information deeply without the pressures often associated with face-to-face instruction. One of the benefits of asynchronous online learning is that teachers spend more time focusing on instructional goals rather than classroom management issues (Anderson & Dron, 2011). Despite these advantages, it should not be assumed that online instruction is superior or sufficient on its own. Both online and face-to-face learning have unique advantages and limitations, which is why the concept of blended learning is crucial to leverage the strengths of each mode. As argued by Sung-Jae (2020) blended learning aims to harness the strengths of each mode to ensure high-quality instruction.

The drawbacks of online learning are well documented. Serttaş and Kasabalı (2020) indicated that students struggled to manage time due to distractions from online activities, including instant messaging and internet browsing. Many other researchers have reported similar findings. For example, Yeboah and Smith (2016) reported that participants in their study struggled with time management in online learning. This shows that online learning demands self-discipline and motivation, which some students may struggle to maintain (Eckhaus & Davidovitch, 2023). According to Rigo and Mikuš (2021), the primary disadvantage of asynchronous online learning is the lack of personal engagement and the ability to discuss and collaborate with others. Rigo and Mikuš (2021) add that lack of immediate feedback may provide issues in keeping students motivated in online contexts. As noted by Lalima and Dangwal (2017) immediate feedback benefits both teachers and students during the teaching and learning process.

Jurs and Špehte (2021) noted that in face-to-face learning, teachers can quickly explain concepts, instructions, and feedback verbally. However, online instruction requires teachers to clearly write down their thoughts to ensure all students understand. In other words, feedback is delayed because it depends on when it was received by both parties in asynchronous settings. Costado Dios and Piñero Charlo (2021) noted that, in cases where students fail to grasp concepts in face-to-face instruction, practical experiences can be conducted to support learning.

This is limited in online environments as students may not have manipulative materials at home Although virtual laboratories can be used (Lalima & Dangwal, 2017), these require advanced digital skills for both teachers and students. Bušelić (2012) contends that asynchronous learning does not provide instant feedback, whereas in a contact classroom setting, learners' performance may be tracked immediately through questions and informal testing. As Fadde and Vu (2014) point out, asynchronous instruction presents less chances for interactions that occur naturally during contact sessions. According to the study conducted by Johnson et al. (2000) in Costado Dios and Piñero Charlo (2021), in face-to-face instruction, students were able to maintain a dialogue as compared to online instruction. They add that students had the opportunity to receive multiple and diverse examples and illustrations from the instructor, which were of poor quality in the online environment. This further highlights the importance of focusing on the strengths of each mode to support blended instruction as some aspects or features can be found in one mode and not the other.

Bao (2020) argues that teaching requires significant teaching tools such as body language, facial expressions, and the voice of the teacher. These important tools are difficult and almost impossible to use through screens, in contrast, contact sessions allow students and teachers to express themselves without the need for a dialogue. This can be recognised through facial expressions, and the teacher can instantly attend to the query. Such instances highlight the significance of face-to-face instruction. In support of this view is Ishtiaq et al. (2024) who found that students preferred face to face learning over online learning, citing the actual presence of their teachers as a motivating factor. Similarly, Bao (2020), revealed that most participants preferred face to face instruction because they believed that teachers' body language improved their understanding and ability to learn. Lalima and Dangwal (2017) add that face-to-face lessons provide an interpersonal or human dimension to the teaching and learning process, which can be motivating for both teachers and students.

The factors listed above are internal factors that affect teaching and learning in both online and contact sessions. It is also important to note that external influences are present in both contexts and have the potential to impede the success of blended instruction. For example, several scholars highlight that the success of online learning is dependent on teachers and students' digital skills (Manca & Meluzzi, 2020; Ferri et al., 2020). Considering that online learning requires the use of technology, some learners or teachers may not be fully competent. Tadese and Muluye (2020) as well as Yeh and Tsai (2022) noted that lack of internet connectivity, limited connectivity, or unstable internet may hinder the success of online instruction. The lack of access to devices, the high cost of internet access, a perceived lack of interest among teachers, and perceived ineffectiveness are the key challenges to e-learning adoption in South African public schools within poor communities (Chomunorwa & Mugobo, 2023). Likewise, Baser et al. (2021) found that students experienced limited internet access because of their geographical location, or because of limited finances with which to purchase internet packages. This supports the viewpoint by Barrot et al. (2021) who argue that students' backgrounds play a role in online instruction. He asserts that students from lower socioeconomic backgrounds have less access to online learning resources, a limited space for learning at home, and a lack of high-quality internet. Likewise, Cıgdem and Ozturk (2016) noted that a reliable internet connection is essential for online learning since connection issues can lower student engagement and motivation. In support of this view are findings from Ishtiaq et al. (2024) study, in which participants pointed out that face to face learning saves time since there is no communication breakdown. The viewpoints from the above scholars indicate a crucial prerequisite for online learning which is access to technological devices, internet and digital skills.

To note the importance of the above-mentioned factors, Beaunoyer et al. (2020) argues that online learning presents issues of inequalities in accessing technological devices, and a lack of conducive physical spaces to carry out the teaching or learning process. Although their study was conducted in the context of Canada, similar studies in South Africa have been conducted and reported the same findings (see Mahaye, 2020; Gumede & Badriparsad, 2022), just to name a few. The external factors noted in online sessions are also noted in contact sessions. For example, Lalima and Dingwal (2017) point out that the improper student -teacher ratio affects learning as teachers fail to meet all students' needs. This is true particularly in the South African schools in which the teacher fails to meet all learners' pedagogical needs due to the number of students. Noting the disadvantages and opportunities of these two modalities situates this study within the context of understanding the requirements for blended instruction. This understanding is critical in highlighting aspects that may influence the study's results, given that the study focuses on exploring both modes.

2.11. Main requirements for supporting blended teaching and learning

The following review aims to link theory with practice in terms of discussing the prerequisites for successfully implementing blended instruction, specifically the role of a teacher in blended settings. Several scholars agree that implementing blended instruction is not an easy task (Lalima & Dangwal, 2017; Masadeh, 2021). Thus, the success of blended instruction has been found to be influenced by several factors. Lalima and Dangwal (2017) noted that, while blended instruction is student-centred, the teacher remains at the centre of the teaching and learning process. Similarly, Sharma (2019) notes that the role of the teacher in blended learning has evolved to the point where it is impossible to implement blended learning without teachers. So, what exactly is it about the teacher's contribution that is so essential in blended learning settings? According to Lalima and Dangwal (2017), teachers must possess the necessary training and expertise to integrate contact and online instruction for blended learning to be successful. Rani et al. (2020) add that teachers must be technology-savvy for this integration to be successful.

Teane (2024) pointed out that teachers' competence with technology is a prerequisite for implementing a blended learning strategy. Garzon and Garzon (2023) also highlighted the importance of teachers' skills in their study, which examined the connection between instructors' self-efficacy, digital literacy, and technology profile in blended learning. The findings from the study revealed that teachers' self-efficacy in integrating technology is higher when they possess strong digital literacy abilities. The study concluded that teachers' digital literacy and self-efficacy are crucial components of the blended learning approach's effectiveness. Given that blended instruction involves teachers working online with technological devices, it is not surprising that the majority of research highlights expertise and skills as essential components of successful instruction. Even in the context of this study, teachers’ skills to record online videos were of importance.

Despite the importance of expertise and digital skills, literature reveals that teachers typically lack these skills (Hlatshwayo 2022; Philemon 2022; Shava 2022). Using South African schools as an illustration, private and affluent schools were able to adapt their educational programs during the pandemic by utilising digital learning resources and combining face-to-face and online instruction (Maree, 2022). This was not the case with many schools in disadvantaged communities (Mahlangu, 2021 in Maree, 2022). While there are several factors influencing these schools' ability to implement blended learning, researchers make explicit reference to the issue of inadequate training. According to Jantjies (2020), many educators in South Africa particularly lacked sufficient formal training to facilitate blended learning or effectively implement online learning.

The very mention of training as a requirement suggests that there is a lack of necessary skills to facilitate blended instruction. Sharma (2019) suggested the following: schools should be given resources to help with the implementation of technological literacy training, and training for teachers in this area should be given high priority. Furthermore, Sharma (2019) adds that training in computer skills must be part of the teacher's professional development. Technology is a key component in blended learning, but it also requires teachers' and students' technological competence. When these two elements are unified, blended learning may prove to be successful. Although digital skills are a necessity in blended instruction as highlighted by several scholars, a holistic understanding of blended instruction is not complete without a clear link between technological skills, content and pedagogy. This implies that knowledge practices that teachers should possess for them to be able to teach effectively in blended contexts also need to be considered as part of teachers' training for blended instruction.

In addition to digital skills, teachers' and students' attitudes toward blended learning are one of the other factors influencing the successful implementation of blended instruction. According to Das (2021), maintaining the blended learning process can be greatly impacted by the attitudes of both teachers and students. Lalima and Dangwal (2017) argue that the success of a blended learning process necessitates teachers who have a broad perspective, are adaptable, and are willing to embrace change. As argued by Jeffrey et al. (2014), teachers who do not see the positive benefits of online learning are less likely to develop successful blended learning programs. The resources available to teachers to enable blended instruction are closely correlated with their attitudes. Ma'arop and Embi (2016) point out that some teachers view blended instruction as a burden due to the increased workload, time constraints, pedagogical and technical skills needed to conduct blended learning. Krasnova and Shurygin (2019) make similar arguments relating to inadequate training: they contend that teachers are reluctant to use blended learning because they lack the necessary expertise. The problem isn't that teachers resist change; rather, it's that they need a little pushing in the right direction to accept the changes. This push could come in the form of resources and the necessary training. As argued by Jeffrey et al. (2014), blended instruction will not live up to its promise of improved learning unless teachers are motivated to reconsider and create new curricula that give students access to a wider range of learning opportunities.

2.12. Reimagining blended instruction: lessons from the post-pandemic era

Süner-Pla-Cerdà et al. (2023) states that scholars in education had predicted that the benefits of online instruction would continue even when the pandemic passed. These predictions were affirmed by the continued relevance of blended instruction for a range of institutions after the pandemic. They were later followed by recommendations for adopting a blended approach as a global instructional method across all educational levels. Following the pandemic, scholars such as Van der Westhuizen and Hlatshwayo (2023) recommended blended instruction to support flexible learning and teaching practices in higher education institutions. This argument assumes that blended instruction may provide flexible solutions to changing educational landscapes by combining the benefits of online and face to face learning. Mahlaba and Sekano (2023) argue in a similar vein, suggesting that higher education institutions should prioritise the development of blended learning approaches. They believe that combining online and in-person learning can improve educational experiences while also meeting varied learning demands. Similarly, Singh et al. (2021) contend that blended learning is the way of the future and offer suggestions for effective blended course instruction. They further assert that educators and school administrators ought to focus on developing the necessary infrastructure to support blended learning approaches.

In a similar vein, Kayi (2024) investigated how digital technology influenced the educational experiences of instructors and students during COVID-19. The study found that participants preferred face to face to the online component of blended instruction. These findings are unsurprising given that most institutions were adapting to the shift from contact sessions to online learning. Based on these findings, Kayi proposed that higher education institutions should develop online learning frameworks that complement 21st-century pedagogical approaches. While the above-mentioned recommendations pertain to higher education, several scholars proposed recommendations targeting the basic education sector. For instance, Damon and Omodan (2022) recommended the provision of adequate online teaching resources for implementing blended teaching and learning methods in South African schools. Likewise, Mmakala and Maphalala (2023) explored the emerging landscape of blended learning and teaching in South African secondary schools following the pandemic era. The study's conclusions emphasised the need for pedagogical support and continual professional development to guarantee the success of blended learning programs. Making a similar argument, Olawuni and Mavuso (2022) contend that blended learning should be supported by schools even after the pandemic.

A closer analysis of the reviewed literature indicates that most recommendations are focused on higher education contexts, while basic education and primary levels appear to be overlooked. If the education sector is to be prepared for future disruptions, all levels of education must be prepared thus a comprehensive blended approach is required. There is no doubt that the recommendations are valid if educational institutions intend to be adaptable to growth and transformation. As argued by Al- Ansi and Al-Ansi (2020), education's future depends on educational institutions' capacity to adopt ICT and adjust to new circumstances. Janse van Rensburg and Oguttu (2022) argue that the post Covid-19 era has highlighted the importance of exploring the use of blended learning in educational spheres.

Although the recommendations in support of blended learning are valid, the emphasis in its implementation is on infrastructure (Singh et al., 2021), self-reliance, competency, and access to resources (Buabeng-Andoh, 2012; Maimun et al., 2017). On the other hand, Mmakola and Maphalala (2023) focused on measures that can support motivation and engagement in blended instruction context while Azevedo and Azevedo (2020) emphasise the importance of bridging the digital divide in successfully implementing blended learning methods. Notably, the above-mentioned aspects may lead to improved accessibility to knowledge in general but reveals little about the pedagogical underpinnings in blended settings.

2.13. The teaching and learning of organic chemistry

According to Cooper et al. (2019), organic chemistry is a fundamental topic in chemistry that plays an important role in our daily lives. Its role cannot be underestimated as it impacts modern science and technology (Chang & Goldsby, 2016). The role of organic chemistry generally expands to the food we eat, clothing items, plastics, soups we use and pharmaceutical drugs (Ebbing & Gammon, 2017). Holme (2023) adds that organic chemistry has played a rich role in the development of the field of chemistry and in the teaching and learning of chemical science. On the other hand, Lopez et al. (2011) contend that organic chemistry is woven throughout physical, life, and applied science courses; as a result, a weak foundation may have a lasting negative impact on future STEM performance and even prevent the development of a strong STEM workforce (Science (S), technology (T), engineering (E), and mathematics (M).

Although organic chemistry is presented in the South African CAPS curriculum as a topic within Technical Sciences rather than as an independent subject, this study conceptualises it as a body of scientific knowledge that exemplifies how disciplinary concepts are structured, connected, and applied across contexts. Positioning organic chemistry in this way moves the discussion beyond curriculum content to the epistemic processes through which teachers and learners build, integrate, and legitimise knowledge. This framing aligns directly with the study's focus on integrative knowledge building and provides a foundation for analysing the pedagogical practices that shape understanding in both online and contact learning environments.

Boateng (2024) states that organic chemistry is a branch of chemistry that deals specifically with the study of molecules primarily consisting of carbon atoms. Abukari et al. (2023) and DBE (2014) add that the topic examines the structure, composition, reactions, and preparation of carbon-containing compounds. Since organic chemistry as a topic has many important applications in our everyday life, any negative outcomes relating to its teaching may have detrimental effects. Over the years, a great deal of research has shown that organic chemistry is a difficult topic and one that many students have misconceptions about. According to Salame et al. (2019), certain aspects of organic chemistry are extremely challenging for teachers and students to understand and explain during the teaching and learning processes. Since the early 2000s, there has been extensive documentation of the challenges associated with teaching and learning organic chemistry. For example, Taber (2002) and Johnstone (2006) noted that students find it difficult to comprehend how organic compounds are drawn and represented. Taagepera and Noori (2000) identified that isomerism as a difficult concept to comprehend. Students struggle to comprehend the properties of organic compounds, according to Anderson and Bodner (2008), while Hassan et al. (2004) and Domin et al. (2008) found that classifying organic compounds presents difficulties. In addition, Davis (2010) identified aromatic hydrocarbons as a difficult concept.

According to earlier studies, differentiating functional groups poses challenges to students (Ayalew & Ochonogor, 2015; O'Dwyer and Childs, 2017). Talanquer (2018) noted that students frequently struggle to establish the connection between structure representations and the related chemical and physical properties. Additional research by Adu-Gyamfi et al. (2017) revealed that students' difficulties with IUPAC naming of organic compounds included being unable to determine the parent chain's correct number of carbon atoms as well as identifying the substituent or functional groups. These difficulties reflect a broader epistemological issue which shows that students often struggle to integrate procedural, conceptual, and representational forms of knowledge within organic chemistry. This aligns with the study's focus on understanding how different knowledge forms can be integrated during teaching and learning.

South African chemistry classrooms are not an exception, for example the diagnostic reports of the National Statement Curriculum from 2018 to 2024 also show that common errors and misconceptions that learners have are primarily associated with the topic of organic chemistry; these errors and misconceptions are like those mentioned above. This reports further reveals that difficulties associated with the topic are persistent up to this day. This persistence highlights the need to examine not only what knowledge is taught but how it is structured, transmitted, and transformed during classroom interaction. These concerns lie at the core of the Legitimation Code Theory (LCT) and to understanding the autonomy pathways that shape integrative knowledge building in South African contexts.

O'Dwyer and Childs (2017) state that chemistry concepts are generally associated with a high level of abstraction, which requires students to think in three dimensions. As noted by Hanson (2014; 2016) a barrier to understanding organic chemistry for students is their failure to comprehend the nature of matter and make connections between the three representational levels of matter: macroscopic, microscopic, and symbolic representations. As argued by Salame et al. (2019) understanding the relationships between the microscopic, macroscopic, and symbolic levels of matter is essential to learning organic chemistry. However, these representations demand that both students and teachers have a solid conceptual grasp of the topic to move past the abstractions and understand the topic. From an LCT perspective, these challenges can be interpreted as difficulties in shifting between different knowledge codes. Teachers' ability to move flexibly between autonomy codes may therefore determine how successfully learners integrate different forms of knowledge in organic chemistry.

Often research highlights difficulties relating to students, however a study by Adu-Gyamfi and Asaki (2022) reported that even teachers have conceptual difficulties with organic chemistry. Adu-Gyamfi and Asaki (2022) then emphasised the need to pay attention to teachers' difficulties in assisting students in understanding organic chemistry. They argue that doing so will be a better way of addressing students' weak performance in the topic. This recognition situates teachers as critical agents of knowledge building which is a central focus of this study. It further highlights the importance of exploring how teachers' knowledge practices, in both online and contact modes, shape learners' understanding of scientific knowledge in organic chemistry.

Several studies have identified effective methods for teaching organic chemistry (Bretz & McClary, 2015; Nik Hassan et al., 2022). Grove and Lowery Bretz (2012), as cited by Sukmawati (2020), implemented a spiral curriculum in which organic chemistry concepts are revisited throughout the syllabus with increasing complexity as students' progress. Stull et al. (2012) proposed using concrete models to teach molecular structures, while Talib et al. (2012), also cited in Sukmawati (2020), introduced the Simple Explicit Animations method. Additionally, some teaching approaches emphasise connecting theoretical knowledge to real-world applications, helping students recognise the relevance of classroom learning (Bhattacharyya & Bodner, 2018; Bodner & Elmas, 2020). In other cases, organic chemistry concepts were taught using the flipped classroom approach under the guidance of educators, yielding positive outcomes (Cormier & Voisard, 2017; Luong, 2021; Oppong et al., 2022; Serhan et al., 2019; Tekane et al., 2020).

Some scholars have focused on learning processes that establish connections and intersections in teachers' and students' reasoning. Strategies such as collaboration, cooperation, hands-on activities, and problem-based learning have been identified as effective in enhancing students' higher-order thinking, academic achievement, and retention in organic chemistry (Abukari et al., 2023; Cooper et al., 2019; Deng & Flynn, 2021; Sabitu et al., 2020). Additionally, the NSC diagnostic report for 2024, suggests the usage of simulations to support understanding of IUPAC nomenclature rules and frequent independent practice for learners (DBE, 2024). This further highlights the need to incorporate technology to foster understanding of organic chemistry concepts. This evidence also points to the value of integrating technology within blended learning environments which is a core concern of this study. In these settings, online and contact sessions complement one another in supporting deeper understanding and more meaningful engagement with abstract chemical concepts.

2.14. Chapter summary

This chapter reviewed literature that is important to understand the objects of the study. Bodies of knowledge expanding understanding of knowledge building were discussed. In addition, the chapter highlighted knowledge focused on the concept of blended instruction including the pre-requisites for this mode and models governing teaching and learning in these contexts. Finally, literature that focused on gaining insight on the teaching and learning of organic chemistry was discussed. The chapter further highlighted teaching strategies that may be deemed useful in fostering knowledge building in organic chemistry. The next chapter focuses on unpacking theoretical underpinnings of this study.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1. Introduction

The aim of this chapter is to provide a detailed account of the theoretical framework guiding this study. A theoretical framework outlines what to look for in the data, how to think about observed data and how to present findings considering existing theories (Kivunja & Kuyini 2017). Simply put, the theoretical framework provided a lens with which to view the data. According to Rocco and Plakhotnik (2009), a theoretical framework entails the presentation of a specific theory as well as empirical and conceptual work on that theory. Merriam (2001) defines the theoretical framework as the study's structure, scaffolding, and frame. This study draws on the Legitimation Code Theory (LCT) as the lens with which to view and analyse the data, with a specific focus on autonomy codes to explore how the variety forms of knowledge structures and practices can be integrated during teaching processes in both online and contact modes of instruction.

3.2. Legitimation Code Theory (LCT)

Legitimation Code Theory (LCT) is a multi-dimensional conceptual framework for researching and transforming practice (Locke and Maton, 2019). It is built upon Bernstein's code theory and Bourdieu's field theory, among others (Martin et al., 2020). Fagan (2020) adds that it explores the fields of social practice to identify their underlying structural principles while Xie (2021) indicate that it is a sociological framework for knowledge practice, and thus it is a practical theory of practice (Maton et al., 2015). The LCT aims to conceptualise the underlying principles that generate discourses, knowledge structures, curricular structures, and learning forms (Maton, 2010).

In this study, the focus is placed on integrative knowledge building as a form of knowledge structure that is observed in educational practices. As argued by Clarence and Mckenna (2017), LCT enables a firmer focus on the structure of knowledge. A solid understanding of how educational practices and educational discourses work with knowledge is described by tracing teachers' ability to build knowledge that is integrative over time in their lessons. The practical aspect of this theory provides a thorough comprehension of what happens in instruction, precisely in online and contact instruction. As a vehicle for teachers' empowerment, this theory provides teachers with tools for improving their own teaching and maintains that teachers are the best experts in their classrooms (Amundrud et al., 2020). Garraway and Reddy (2016) add that when teachers are aware of knowledge structures, it becomes easier for them to help students comprehend how different parts of knowledge can be brought together thus allowing students to improve their learning. LCT provides an approach to analyse and inform practices since teachers are given the power to examine and improve their teaching practices.

The LCT is comprised of five core dimensions namely: semantics, specialization, autonomy, temporality, and density that help analyse how different legitimation codes organise practices, dispositions, and contexts within a field of knowledge or activity. Figure 4 shows the LCT dimensions and their breakdown.

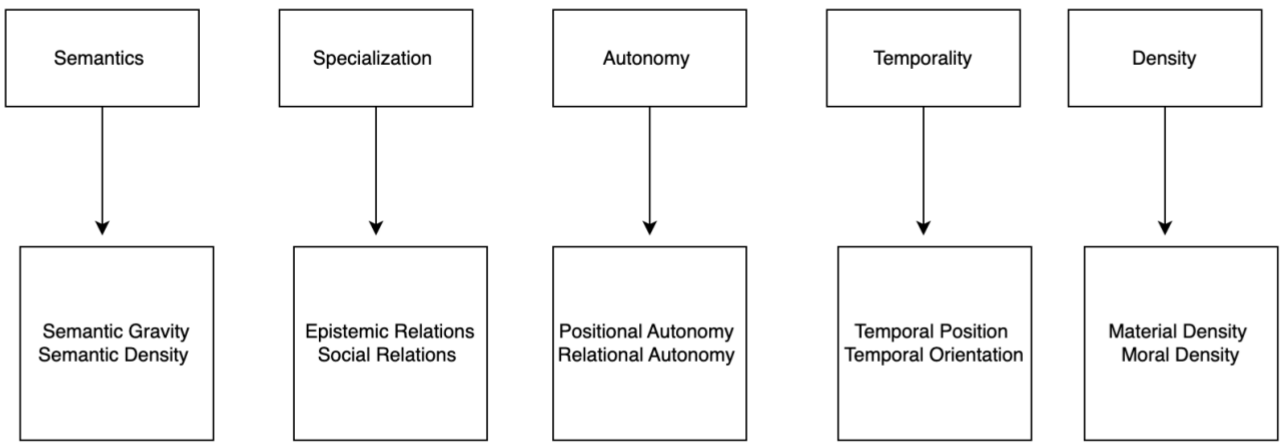


Figure 4: LCT framework dimensions

Each dimension of LCT, according to Locke and Maton (2019), consists of concepts that explore a different set of organising principles underpinning actors' practices. In this study actors are the teachers teaching the topic of organic chemistry for technical sciences grade 12. Maton et al., (2020) argue that different dimensions do not refer to different practices but rather examine different organisational principles underpinning practices, so the same practices may be underpinned by all dimensions. Additionally, they depend on the problem and context at hand (Maton et al., 2020). For this study, the concept of autonomy codes (Maton & Howard 2018) is drawn specifically on as a set of organising principles that determine what constitutes integrative knowledge building in the observed lessons.

3.3. Autonomy codes

Autonomy codes, according to Maton and Howard (2020), start with the simple notion that any set of practices, ideas, or beliefs is made up of constituents that are structured in specific relationships. Constituents and their relations can take a wide variety of forms, for example, knowledge practices can assume strong and weak relations depending on how knowledge is presented. According to Locke and Maton (2019), actors, ideas, objects, and artefacts can be constituents, and relations between them can be based on explicit processes, tacit methods of working, mechanisms, rules, and so on. Put simply, practices have different elements such as ideas, concepts, individuals within the practice etc and the relationship among the elements may include aims and procedures, all these combined explain the concept of autonomy. Thus, autonomy codes look into the degree of insulation that exists between constituents and the foundations of their relationships (Maton & Howard, 2020). To put it differently, the concept looks at how practices construct various degrees of insulation around their constituents and how those constituents relate. Positional autonomy (PA) and relational autonomy (RA) are the two underlying concepts that define the autonomy dimension (Shay, 2016). Stronger PA and RA is denoted by + while weaker PA and RA is denoted by – along a continuum of strengths. Stronger represents greater insulation, while weaker represents lesser insulation (Maton & Howard, 2021). Autonomy codes are mapped on the autonomy plane and tracked through time using autonomy profiles (Wilmot, 2019).

3.3.1. Positional autonomy (PA)

Positional autonomy refers to the degree to which a constituent in one context is insulated from constituents in other contexts; a higher level of positional autonomy indicates a greater degree of insulation (Maton and Howard, 2018). Stronger positional autonomy (PA+) indicates that constituents within a specific context or category are distinctly separated from those of other contexts or categories. In contrast, weaker positional autonomy (PA–) reflects less clearly defined distinctions, characterised by poorly insulated positions (Maton & Howard, 2021). Positional autonomy in education serves to distinguish between elements that are deemed "inside" and those that are "outside" a particular knowledge practice (Blackie et al, 2022). Maton et al., (2016) assert that enquiries regarding the origins of practices or knowledge, whether internal or external to the school science curriculum, pertain to differing degrees of positional autonomy. Blackie et al. (2022) characterise aspects deemed 'inside' practices as exhibiting stronger positional autonomy, while those regarded as 'outside' demonstrate weaker positional autonomy. In other words, ideas or concepts coming from within a specific topic of science can be denoted as PA++ (stronger positional autonomy), general scientific knowledge as PA+ (slightly stronger), other academic knowledge as PA− (slightly weaker) , or every day and common understandings as PA − − (weaker). These strengths of PA can be applicable in teaching the topic of organic chemistry are shown in Table 1 below. For integrative knowledge building to occur, the teacher must gradually weaken and strengthen positional autonomy throughout the lesson.

Table 1: Positional autonomy codes and their associated meanings

Code	Indicator/meaning
PA++	The teacher describes ideas from the topic of organic chemistry.
PA+	The teacher focuses on general knowledge regarding science; the ideas are not organic chemistry concepts but from the technical science curriculum in general.
PA−	Teachers use ideas that are academic but are outside of the technical science curriculum, i.e., history, business studies, etc. This is another educational knowledge.
PA − −	The teacher explains ideas that are not linked to any school subjects, i.e., everyday knowledge or common understanding.

3.3.2. Relational autonomy (RA)

Relational autonomy refers to a particular aspect of knowledge (Maton, 2005), namely the purpose for which knowledge and practices are used. Whenever we ask where the purpose for knowledge and practices being used is predominantly situated, we are referring to relational autonomy (Maton et al., 2016). According to Maton and Howard (2018) relational autonomy (RA) describes the strengths of the purposes (goals and aims) suitable in a particular practice or context. Relational autonomy can also be stronger (RA+) or weaker (RA). Stronger relational autonomy (RA+) suggests that the means of relating constituents are largely unique to specified practices, whereas weaker relational autonomy (RA–) shows that the ways of relating can be borrowed from or shared with other sets of practices (Howard & Maton, 2020).

Constituents which are uniquely bound to a specified practice consist of autonomous principles while relating constituents that are taken from somewhere else explain heteronomous principles. Thus, stronger relational autonomy (RA+) suggests that the purposes, aims and ways of operating look inward to that specific set of practice, whereas weaker relational autonomy (RA−) suggests that the purposes, aims and ways of operations look outwards to other sets of practices (Maton & Howard, 2020). For example, relational autonomy is stronger when knowledge and practices which could be about science are used to enhance the aims and purposes of the science curriculum (Garraway & Reddy, 2016). Alternatively, when knowledge is used for purposes outside of the science curriculum, relational autonomy is weakened. Relational autonomy is coded according to the four levels of strength, RA++, RA+, RA −, RA − − as presented in Table 2 below which further shows an example of how they can be implemented in the topic of organic chemistry.

Table 2: Relational autonomy codes and their associated meanings

Code	**Indicator/meaning**
RA++	The purposes and aims are to deepen understanding of the concept of organic chemistry.
RA+	The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.
RA −	Purposes speak to other knowledge domains; they are not unique to the understanding of organic chemistry.
RA− −	Purposes and aims carried out do not enhance the learning of organic chemistry or school subjects.

3.3.3. Autonomy plane

In LCT, the autonomy plane serves as an analytical instrument for examining the interrelations across various knowledge practices, notably within educational contexts. It elucidates the extent of insulation or emphasis assigned to a particular subject or domain of knowledge within a wider framework. When the two continua of insulation strengths are intersected, an autonomy plane is established and four major autonomy codes are observed: sovereign codes, projected codes, exotic codes, and introjected codes. Figure 5 below shows how positional and relational autonomy are depicted as axes of the autonomy plane.

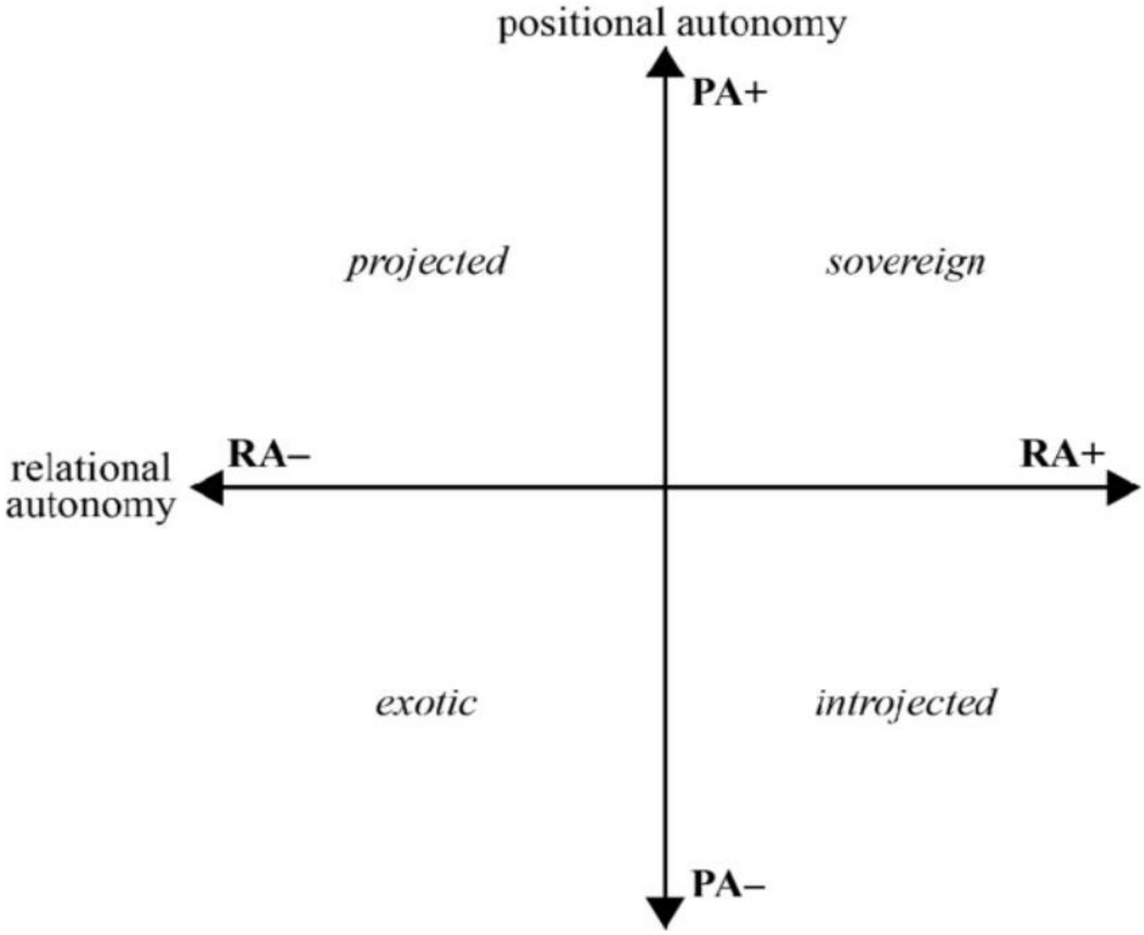


Figure 5:The autonomy plane (Maton and Howard 2018. p.6)

Sovereign codes (PA+, RA+) contrast with exotic codes (PA–, RA–) in that the former has strongly insulated positions and autonomous principles, while the latter has weakly insulated positions and heteronomous principles (Zhao, 2020). Similarly, projected codes (PA+, RA–) differ from introjected codes (PA–, RA+), and their distinct legitimacy is based on strongly insulated positions with heteronomous principles and weakly insulated positions with autonomous principles, respectively (Zhao, 2020). Table 3 shows descriptions of autonomy codes and examples of how they can be enacted in the topic of Organic chemistry.

Table 3: Autonomy codes and their examples in the topic of organic chemistry

Autonomy codes	Description	Example in the topic of organic chemistry
Sovereign codes (PA+,RA+)	▪ PA and RA are both stronger. ▪ Positions are strongly insulated and consist of autonomous principles ▪ Constituents are linked to the context and behave in accordance with their specified operating methods. ▪ Sovereign codes are where the scientific home is	The teachers explain ideas from organic chemistry and carry out purposes and aims that deepen understanding of the topic.
Exotic codes (PA−,RA−)	▪ Weaker PA and weaker RA. ▪ Positions are weakly insulated and include heteronomous principles. ▪ Constituents are linked to other contexts, and they behave in ways that are like those in other contexts or categories. ▪ Knowledge practices deviate from scientific procedures and understandings	Ideas explained are outside of the technical sciences curriculum and purposes and aims carried out do not enhance the learning of organic chemistry.
Introjected codes (PA−,RA+)	▪ Weaker PA and stronger RA. ▪ Weakly insulated positions with constituents which are bound to a specific set of practice (autonomous principles). ▪ Knowledge practices that use operations from science in a context that does not target the learning of organic chemistry or science concepts.	The teachers explain ideas that outside of the topic of organic chemistry using operations from within the discipline.
Projected codes (PA+, RA−)	▪ Stronger PA and weaker RA. ▪ Positions are strongly insulated with constituents that emanate from elsewhere ▪ Knowledge practices that target the teaching and learning of scientific concepts but use operations that do not enhance the learning of those concepts.	The teachers explain ideas from organic chemistry using procedures that do not enhance the learning of organic chemistry.

Identified pathways are not definite and thus cannot be treated as descriptions of autonomy pathways to be observed for every single lesson in this study. What this entails is that in a lesson, pathways can remain in one code or move through the codes. According to Maton and Howard (2018), there is an unlimited number of potential movements around the autonomy plane. Maton and Howard identified four kinds of pathways that emanate from the shift of autonomy codes shown in Figure 6 below. These can be used to examine classroom practices that take place over time in a lesson.

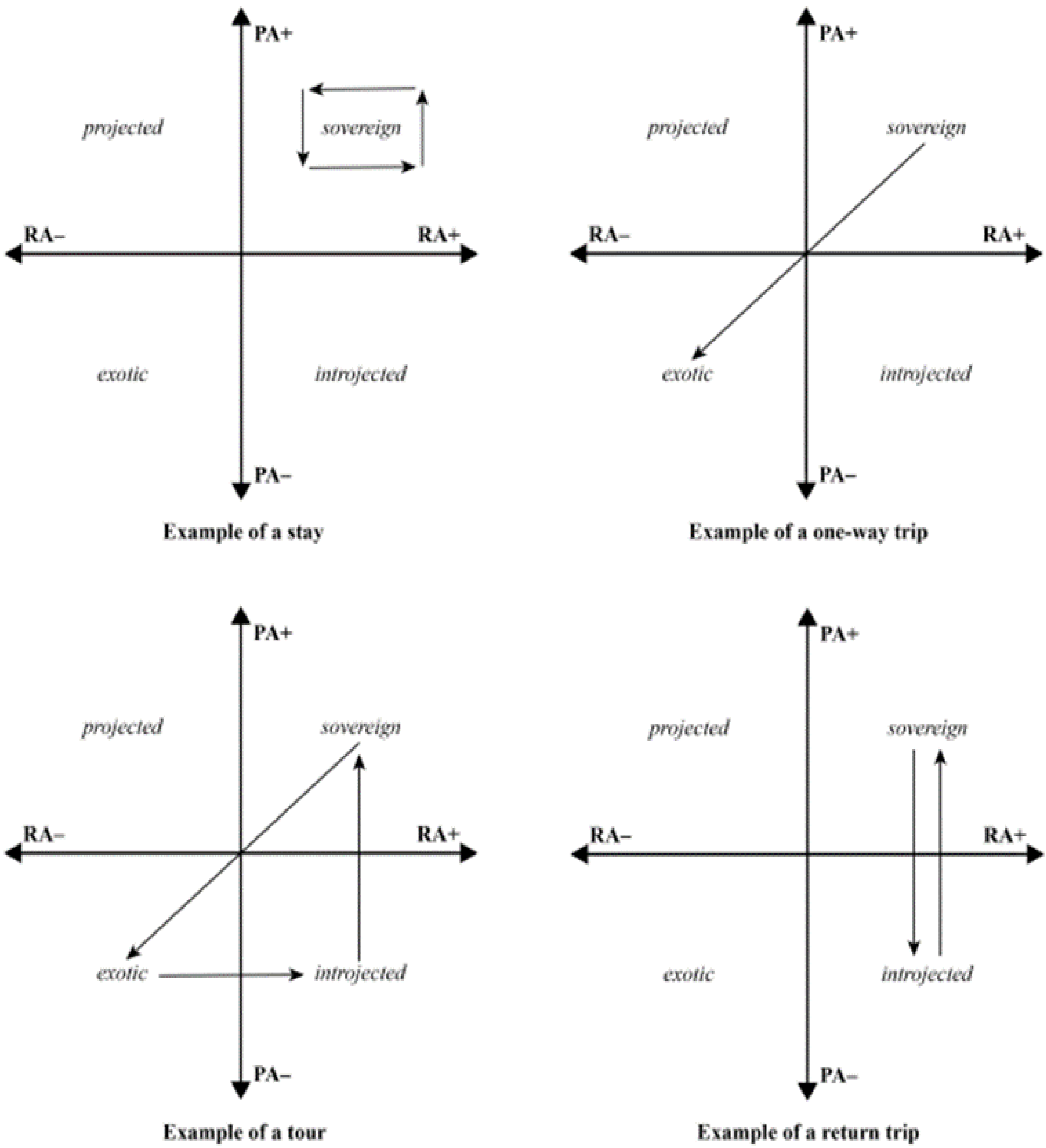


Figure 6: Examples of autonomy pathways (Maton and Howard, 2018)

- Stay pathways are formed when autonomy tours remain within the same code,

- One-way trips are formed when autonomy tours begin in one code and end in another code.
- A tour is formed when autonomy pathways begin in one code, shift through one or more codes and return to where they started.
- Return trips are formed when there is movement from one code to the next and then back to the original code.

Considering the complexity of the teaching process, this requires teachers to be able to integrate knowledge from various sources during instruction. Explanations of core concepts should not reside in one quadrant but shifts and drifts should be observed if the goal is to build knowledge that is integrative.

For organic chemistry lessons, the examples below show movements in pathways that can be implemented by teachers.

- Teachers can *stay* within a specific code, for example staying within the sovereign code (PA+; RA+) through focusing on ideas that describe the concept of organic chemistry in relation to the prescribed curriculum (PA+) and then introducing purposes that are aimed at deepening learner understanding of the concept of organic chemistry (e.g. an experiment) (RA+).
- Teachers can take a *one-way trip* from the sovereign code (PA+ and RA+) to the exotic code (PA− and RA−) through starting off by focusing on ideas and procedures from the topic of organic chemistry and then deviating to the adoption of everyday knowledge and procedures that have little to do with the teaching and learning of organic chemistry. What stands out in a one-way trip is that the teacher does not go back to the sovereign code but leave explanations on the exotic code, thus understanding of the organic chemistry concepts remains at everyday understanding without a link to the curriculum knowledge. The teacher does not bring the knowledge back home (sovereign code) as Maton and Howard (2020) would argue, such a practice does not depict integrative knowledge building since integrative knowledge building is explained using a complete tour between codes as described below.
- They can *complete a tour* and during a tour, the teacher ventures off to various knowledge sources, but knowledge or understanding is eventually brought back home (the scientific knowledge being taught in the case of organic chemistry). When

autonomy tours are incorporated in the teaching and learning process, we observe a situation where the teacher uses diverse sources of knowledge to help learners understand the complex and abstract scientific concepts.

- Finally, the teacher can take a *return trip* which is the simplest form of tours that move back and forth between two codes (Maton and Howard, 2018). According to Maton and Howard, tours have the potential for integrative knowledge building as compared to a one-way trip or stay pathways. In teaching organic chemistry for example, the teacher may start by focusing on explaining concepts within organic chemistry (sovereign code), shift to incorporating everyday knowledge (exotic code) and then repackages understanding through shifting back to organic chemistry concepts as prescribed through the curriculum. The key is not to leave knowledge at the everyday level but to repackage it back into disciplinary understanding.

In this study, the autonomy plane in Figure 5 is adapted to show how the autonomy codes can be traced, by varying levels of autonomy strengths to produce eight levels of strengths for positional and relational autonomy. These are illustrated by (PA++, RA++) and (PA+, RA+), for *sovereign codes,* (PA − −, RA− −) and (PA−, RA−) *for exotic codes,* (PA − −, RA++) and (PA−, RA+) for *introjected codes* and (PA++, RA− −) and (PA+, RA−) for the *projected codes*. Within these codes the former is stronger or weaker than the latter, for example (PA++, RA++) is more strongly insulated than (PA+, RA+) whereas (PA− −, RA− −) is weaker than (PA−, RA−). Figure 7 shows the degree of strength and weakness of these autonomy codes.

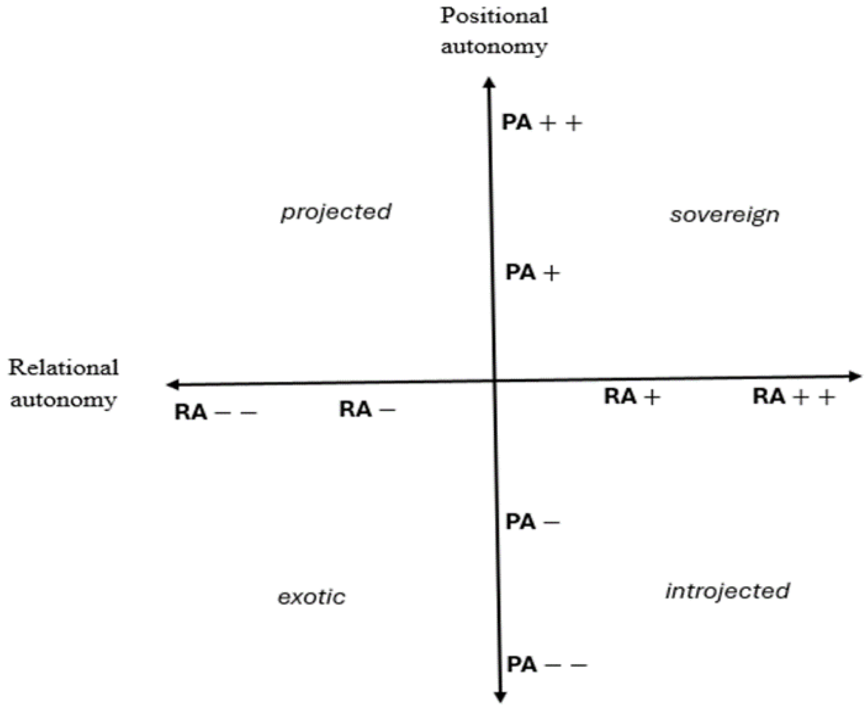


Figure 7: Autonomy plane as adapted from Maton and Howard (2018)

3.4. Targets

Targets are fundamental in integrative knowledge building as they determine how integrative knowledge building may occur in specific contexts. Maton and Howard (2021) explain that whether knowledge is categorised as target or non-target, depends on the study's analysis. Given that this study aims to explore knowledge structures and practices from teachers' perspectives, the target or non-target classification should be identified by teachers instructing grade 12 learners in technical sciences, specifically on the topic of organic chemistry. In identifying targets, it is essential to specify whose target is being considered, as different participants, such as learners in a classroom, may have their own distinct sets of targets. In this study, organic chemistry serves as an illustrative topic drawn from the technical sciences curriculum. Therefore, the targets identified by teachers should be aligned with the curriculum, while the intended purpose of these targets should support and enhance the broader educational goals. This implies that it would be unreasonable for the targets to originate from unrelated curricula, such as biology, or for the teaching purposes to be purely non-academic. Without clearly defined targets, the study's objectives may lack accuracy or even become unattainable, as targets are essential for understanding how integrative knowledge building can take place within specific contexts.

3.5. Translation device

The translation device functions as an external language of description, clearly describing how the varying strengths of the codes are realised in this study (Maton & Tsai-Hung Chen, 2016).). In other words, the translation device explicitly demonstrates what was classified as stronger or weaker positional and relational autonomy and the reason why. The indicators of the translation device demonstrate how PA and RA and the associated codes are realised empirically (Maton & Tsai-Hung Chen, 2016). According to Howard and Maton (2020), researchers must clarify how autonomy codes are manifested within a particular object of study being explored. LCT accomplishes this by developing a translation device which clearly demonstrates how theory and data are related by translating between higher level abstract concepts and empirical concrete data (Maton et al., 2020). As a result of the translation device, researchers can be open and clear about how they are using the theory of LCT in their studies (Amundrud et al., 2020). The translation device can be used to categorise the strengths of positional and relational autonomy as weaker or stronger and further highlights categories for (target and non-target). There are two types of translation devices: the generic translation device (Table 4) and the specific translation device (Table 5).

3.5.1. The generic translation device

The generic translation device as seen in Table 4 below serves as a framework for individual studies to construct specific translation devices that are unique to their research (Maton & Howard, 2018). It was adapted in the following ways:

- First, the two concepts of RA and PA were separated so that the boundaries that exist between these two concepts are clearly demonstrated. This implies that the study then utilises two translational devices, one for PA and the other for RA as highlighted in Table 5.
- Secondly, the first level of the adapted translational device clearly identifies what is of target and what is non-target in the study.
- Thirdly, the second level identified specific codes, (PA++, PA+, PA−, PA− −) and (RA++, RA+, RA−, RA− −) while explicitly indicating why the codes have been categorised in that specific way.

Table 4: Generic translation device (Maton & Howard, 2018 p.10)

PA/RA	1st Level	2nd Level	2nd level
Stronger	Target	core	inner
			outer
		ancillary	inner
			outer
	Non-target	associated	near
			remote
		unassociated	near
Weaker			Remote

3.5.2. The specific translation device

The specific translation devices bridge the gap between abstract concepts related to the theory and the actual data collected in the study. In this study, the specific translation device shows how the classifications of these codes can be mapped in the topic of organic chemistry as shown in Table 5 below.

Table 5: Specific translation device for Positional autonomy (PA) and Relational autonomy

Strength	**Code (PA)**	**1st level Indicator**	**2nd level indicator**	**Code (RA)**	**1st level Indicator**	**2nd level indicator**
Stronger	PA++	Target Content (Inside science curriculum)	The teacher describes ideas from the topic of organic chemistry based on the science curriculum.	RA++	Target Purposes for teaching and learning organic chemistry	Purposes and aims are to deepen understanding of the concept of organic chemistry in relation to the curriculum.
	PA+		The teacher focuses on general knowledge regarding science; the ideas are not organic chemistry concepts, but from the technical science curriculum in general.	RA+		The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.
	PA−	Non-Target (outside science curriculum)	The teacher focuses on ideas that are academic but are outside of the technical science curriculum, i.e. history, business studies, etc. This is another educational knowledge.	RA−	Non - Target Other purposes that have nothing to do with the learning of organic chemistry.	Purposes speak to other knowledge domains they are not unique to the understanding of organic chemistry.
Weaker	PA− −		The teacher explains ideas that are not linked to any school subjects, i.e., everyday knowledge or common understanding.	RA− −		Purposes and aims carried out do not enhance the learning of organic chemistry or school subjects.

3.6. Chapter summary

This chapter introduced the Legitimation Code theory (LCT) as a framework guiding this study. Within the five dimensions of LCT, the concepts of autonomy codes which are positional (PA) and relational autonomy (RA) were chosen to highlight whether knowledge practices that teachers opt for in blended contexts are within or outside the curriculum and whether the purposes and operations used during instruction are used to enhance learning within the science curriculum. The concept of an autonomy plane was explained, as well as translation devices and targets. The next chapter presents the methodology for the study.

CHAPTER 4: RESEARCH DESIGN AND METHODOLOGY

4.1. Introduction

This chapter outlines and justifies how the research outcomes were achieved in line with the study's objectives. It presents the research paradigm, describes the research site, and details the population and sampling procedures. The chapter also discusses and justifies the selected research paradigm, research design, research approach, data generation methods, and instruments for their relevance and suitability. Furthermore, the chapter explains the data analysis process and addresses issues of validity and reliability clearly outlining how the study adhered to each aspect. The chapter concludes with an overview of the ethical considerations observed and how these were adhered to in the study. For this study, the theory of Legitimation Code Theory (LCT) is also integrated into the methodological and analytical approaches by detailing how it informed the framing and data analysis processes throughout the research process.

4.2. Research paradigm

A research paradigm is a fundamental framework or perspective that directs the conduct of research. All research studies are developed and shaped within the parameters of the chosen research paradigm (Killion & Fisher, 2018)**.** Tracy (2013) describes paradigms as preferred methods of comprehending reality, generating knowledge, and obtaining information about the world. A research paradigm encompasses a collection of beliefs and assumptions on the nature of reality (ontology), the process of knowledge creation (epistemology), and the techniques employed to obtain that knowledge (methodology). Chilisa and Kawulich (2012) identified four principles of a research paradigm: ontological, epistemological, axiological, and methodological principles. Ontology is concerned with what defines reality, while epistemology is concerned with what constitutes knowledge, truth, and how people come to know it. Axilogy, on the other hand, is concerned with ethics and value systems, and methodology is concerned with how we should investigate the world (Ligus, 2021). Chilisa and Kawulich (2012) argue that in the context of a research paradigm, these principles are useful for framing a researcher's perspective on a research problem, how they investigate the problem, and the methods to be utilised to answer research questions. It influences the research questions, research method choice, data interpretation as well as the validity and reliability of the study.

The interpretivism paradigm underpins this study. According to Alharahsheh and Pius (2020) the interpretivist paradigm is a research approach that focuses on understanding the subjective meanings and experiences of individuals within their social context. Mustofa (2023) explains that the interpretive paradigm sees social reality as a dynamic process shaped by the individuals involved. This suggests that interpretivism emphasises the detailed, context-specific meanings individuals attach to their experiences and the social realities they construct. Creswell (2007) argues that within the interpretive paradigm, the primary goal of researchers is to grasp the complexity of a phenomenon, rather than to produce generalisations applicable to broader populations. One of the assumptions of interpretivism is that reality is complex and socially constructed (Mustofa, 2023) and can be best understood through qualitative research methods (Awa & Sylva, 2015) which allow researchers to gain deep insights of certain contexts through collection and interpretation of qualitative data unique to contexts (Myers, 2019). According to Kivunja and Kuyini (2017) methods with characteristics that involve researchers being immersed within the realities of participants such as dialogues, reading, writing, and recording research between the researcher and the participants form part of the qualitative research process.

Since this study aims to uncover knowledge structures and practices within specific contexts, it means that data collected is unique to those contexts and cannot be generalised to the entire population of science teachers. Situated within South African high school science classrooms, this interpretivist orientation enabled a close examination of how teachers and learners build knowledge that is integrative within authentic teaching environments. While the findings are not intended for generalisation, they provide transferable insights relevant to similar blended learning contexts.

4.3. Research design

This study falls under the exploratory and interpretive case study research category (Yin, 1994), as its goal is to explore and interpret online and contact sessions as a phenomenon. In research, a case study is defined as an in-depth examination of a current phenomenon in its natural setting (Schoch, 2020). Heale and Twycross (2018) add that a case study is an in-depth, systematic analysis of a single individual, group, community, or other unit in which the researcher explores data related to numerous factors. According to Tellis (1997), a case study can assist in explaining both the process and the outcome of a situation by observing, reconstructing, and analysing the cases under consideration. A case study approach, according to Yin (2003), can be used when the study is focused on answering the 'how' and 'why' questions. This study focused on teachers teaching organic chemistry as a case, where in one case, teachers taught the topic through online sessions, while in another, teachers taught the same topic through contact sessions. In both these cases the aim was to explore how teachers build knowledge that is integrative in their lessons. These distinct cases have been chosen to explore and provide a thick description of how integrative knowledge building occurs in each mode of instruction. The study illuminates how knowledge structures and practices function within a specific context, in this case online and contact sessions, thus a case study research design is more appropriate. Additionally, a case study research design was chosen since it perfectly describes the qualities of a qualitative research methodology (Sevnarayan, 2019).

4.4. Research approach

The three primary research approaches in educational research are quantitative, qualitative, and mixed method approaches (Creswell, 2014). The distinction between qualitative and quantitative research is frequently defined using words (qualitative) rather than numbers (quantitative), or the use of closed-ended questions (quantitative hypotheses) rather than open-ended questions (qualitative interview questions) (Creswell, 2014). The mixed method approach is distinct in that it employs both qualitative and quantitative approaches (Creswell, 2012). According to Creswell (2014), there is generally a link between the paradigm and the research approach that individual researchers embrace in their studies. This means that individual researchers' beliefs, objectives, and problems to be explored will often drive them to adopt a qualitative, quantitative, or mixed methodologies approach to their research. He further alludes that, researchers must consider the philosophical worldview assumptions they bring to the research project, the research design that is tied to this worldview, and the specific research methodologies or procedures that put the approach into practice.

The focus of this study is in exploring a social phenomenon in natural settings, therefore a qualitative research approach within the interpretivism paradigm was appropriate. Qualitative research is useful for comprehending thoughts, views, or experiences, and evaluating non-numerical data (such as text, video, or audio) (Ugwu & Eze, 2023). It often includes data in the form of words instead of numbers (Punch, 2013) usually noted through rich descriptions in interviews and transcriptions from classroom observations in the case of this study. The goal of qualitative research is to understand, explain, explore, uncover, and make sense of the settings, emotions, perceptions, attitudes, values, beliefs, and experiences of a specific group of individuals (Kumar, 2011). Creswell (2014) contends that qualitative research is a method of exploring and interpreting the meanings that individuals or groups attribute to a social or human problem. Denzin and Lincoln (2005) add that it is a contextual activity that locates the observer in the world. Weinreich (2009) indicates that the purpose of qualitative research is to provide the researcher with the perspective of target audience members through immersion in a culture or situation and direct interaction with the people under study. This study involved events in which the researcher was immersed in the world of the participants through observations and direct interviews, with the goal of collecting rich data to answer the research questions.

The notion that a qualitative research approach is based on unique viewpoints implies that the information collected is only accurate at the time it is gathered because those perspectives are subject to change, thus limiting rigidity (Ugwu & Eze, 2023). The qualitative research methodologies employed in this study were intended to aid in the understanding of the meanings that participants assign to social phenomena as well as the mental processes that underpin those meanings. To achieve this, the study first explored how integrative knowledge building occurs in lessons delivered through both online and contact modes. While the study focused on exploring integrative knowledge building in both online and contact sessions. It was important to note that any aspect of online instruction necessitated a conversation on implementation skills.

The advantages of qualitative research are grounded in its focus on thick description, for instance, gathering authentic, detailed, and deep data that explains everyday patterns of interaction and meaning from the point of view of individuals being observed. Denzin and Lincoln (2005), indicate that qualitative data emphasises the properties of entities as well as processes and interpretations that are not scientifically tested or quantified. Given that the study seeks to "gain insight into," "fully comprehend or explore," and "describe" a phenomenon, the qualitative approach thus provides an in-depth sense of how people (participants who are teachers in this study) manage their day-to-day situations (referring to their general teaching practices). In this study, the qualitative approach provided a general description of how teachers build knowledge when teaching the topic of organic chemistry to grade 12 learners using online and contact modes. In the case of online teaching, teachers were required to pre-record videos that were later uploaded for learners to engage with.

4.5. Data generation methods and research instruments

According to Kabir (2016) data collection is the act of acquiring and measuring information on targeted variables in a systematic manner that allows one to answer specific research questions, test hypotheses, and assess outcomes. Kabir (2016) further states that the purpose of any data collection is to obtain high-quality evidence that can be used to conduct rich data analysis and construct a convincing and credible response to the questions explored. Research instruments that were used for this study are: document analysis, lesson observations and interviews. Since all these methods generate descriptive non-numerical data that cannot be represented as numbers, they were identified as relevant for this qualitative data (Taherdoost, 2021).

4.5.1. Document analysis

According to Bowen (2009) document analysis is a tool for systematically studying and assessing written and digital documents. Document analysis, like other qualitative research methods requires the examination and interpretation of data to extract meaning, gain insight, and develop empirical knowledge (Armstrong, 2022). It involves skimming, reading and interpretation of data to make sense of it. In this study, document analysis was used in combination with observations to triangulate data. According to Rapley (2007), the process of triangulation entails merging data from several data collection methods to give the study credibility. One of the advantages for using document analysis as a data collection method is that the research process has no impact on the documents because they are unobtrusive and non-reactive (Bowen, 2009). This suggests that documents are stable, and the researchers' involvement with the documents has little or no effect on the study. According to Bowen (2009), it is critical for researchers to identify documents that are relevant to the research problem and purpose while also determining the authenticity, credibility, and accuracy of the documents chosen. Document analysis was an efficient method in this study, as it required less time by focusing on data selection rather than intensive data collection. It was employed to address the first secondary research question which aimed to establish the targets in the teaching of organic chemistry and to examine how teachers align their instruction with the prescribed technical sciences curriculum. Relevant documents were reviewed to determine the extent of compliance with curriculum guidelines.

The documents analysed included the Technical Sciences Curriculum and Assessment Policy Statement (CAPS) (see *Appendix* E) , teacher's guides and learners' textbooks. The analysis of content prescribed in the CAPS was used to determine the targeted knowledge as depicted by the curriculum in comparison to content enacted while teachers build knowledge that is integrative. The analysis of the teachers' guide and learners' book were aimed at establishing the depth of the content knowledge that is intended for both teachers and learners in the topic of organic chemistry. Through these targets, the study was used to establish whether content set in the curriculum together with teachers' own set targets, determine the knowledge practices that promote or hinder integrative knowledge. Additionally, teachers' own set targets were used to identify whether specific practices exist within or outside of the curriculum.

4.5.2. Lesson observations

Observation is a method of obtaining data by observing behaviour, events, or noting physical characteristics in their natural environment (Ekka, 2021). Observations allow the researcher to use the five senses to describe real life situations, resulting in a "written photograph" of the scenario under investigation (Elandson et al., 1993). One of the benefits of observations is that they allow data to be collected where and when the event is taking place, allowing researchers to see what individuals do instead of depending solely on what individuals claim they did (Taylor-Powell and Steele, 1996). The most significant component in establishing what a researcher should observe is the researcher's purpose for carrying out the study in the first place (Merriam, 1998). Through lesson observations, data was generated to answer the second secondary question to investigate the shift in knowledge structuring patterns when teaching organic chemistry through online and contact sessions and how do these contribute to knowledge building, as well as to partly answer the third secondary question to observe how practices in blended learning environments fostered integrative knowledge building effectively. Lessons were physically observed for contact classes during real time teaching and pre-recorded videos were observed for online lessons.

To guide systematic data generation during both contact and online lessons, an observation protocol (see *Appendix F*) was developed based on the study's objectives and research questions. The protocol outlined specific focus areas aligned with the autonomy dimension of Legitimation Code Theory (LCT), including lesson structure, knowledge practices, integration of knowledge forms, pedagogical strategies, and learner engagement. It further provided a structured format for recording observed activities, knowledge codes, and researcher reflections to ensure consistency and reliability across all observations.

4.5.2.1 Lesson observations for contact sessions

There are two main types of observations: participant observations and direct observations (also known as non-participant observations). According to Kawulich (2012) participant observations entails being present in the research context as both an observer and a participant while direct observations entail observing without interfering with the people being studied in an environment. This study employed non-participant direct observations because observations nether interfered with teachers nor learners, for contact classes and pre-recorded video observations for online classes. Sutton and Austin (2015) describes direct observations as a subtle qualitative research approach for collecting data about some aspect of the social world without directly interacting with its participants. It describes the process of viewing actions, procedures, or acts as they occur. Kawulich (2012) recommends direct observations, where participants are aware that they are being observed, and the researcher is not in any way concealing the fact that they are observing them for research purposes.

In this study, direct observations were done for contact lessons of science teachers during an organic chemistry molecule class. The aim was to observe and identify forms of knowledge structures and practices that enable or hinder integrative knowledge building in the classroom context. Furthermore, the study explored how teachers build knowledge that is integrative over time in their lessons when teaching the topic of organic chemistry. Non-participant direct observation minimised any potential distractions that could arise from the learners being aware that they were being observed. A total of four recordings were captured from four teachers that participated in generating data for contact sessions.

4.5.2.2. Pre-recorded video observations

Video recording, according to Sadalla and Larocca (2004), is suited for examining complex situations like classroom practices, which are full of vibrancy. They add that video recording enables researchers to capture brief and non-repeatable moments that would otherwise go unnoticed. Loizos (2008), posit that video recording is required when a series of human behaviour is complicated and impossible to fully describe in real time by a single observer. The usage of video recording, as well as technology advancements that enable easy video editing, have raised new ethical concerns hence Garcez et al. (2011) argue that images obtained from video recordings should be hidden since images identify subjects more than pseudonyms used in the final text. For this study, video recordings were reviewed independently by LCT members who were not present during the observations, capturing the teaching process as it unfolds during the observed lessons helped improve reliability. These allowed for the capturing of as much data as possible which was then later analysed. Additionally, video recording allowed for the capturing of aspects that may go unnoticed during the teaching and learning process, such as body, facial and verbal language used in real life.

Asynchronous online video observations were used as a data collection method for online sessions. Asynchronous online learning is generally defined as an online teaching approach in which the teacher posts lessons, resources, and assignments online so that students can review them whenever it's convenient for them before the deadline (Zeng & Luo, 2023). The asynchronous online videos used in this study were made available through pre-recorded video lessons, with the focus being on organic chemistry for Technical Sciences learners in grade 12. To reduce delays in video recordings, teachers were given enough time to work on these videos individually prior the lessons and allowed to ask any questions they had about the quality of the videos, the tools needed, and many other aspects that would contribute to making the process more manageable. Pre-recorded videos produced by the teachers were approximately 30-35 minutes long.

4.5.3. Interviews

Interviews are an integral part of qualitative methods in research, which provides an in-depth understanding of social phenomena (Silvermann, 2000). In this study, a social phenomenon in question is the teachers teaching in online and contact sessions. Minhat (2015) argues that interviews are very useful when the researcher aims to explore experiences and insights that may not be clearly portrayed by simply answering a list of questions in a questionnaire. Gill et al., (2008) state that interviews are mostly appropriate when detailed insights are required from participants. Interviews were conducted with participants to gain insight into the knowledge practices that foster integrative knowledge building in blended learning environments.

The value of interviewing is not only because it builds a holistic snapshot, analyses word, reports detailed views of informants; but also, because it enables interviewees to “speak in their own voice and express their own thoughts and feelings (Berg ,2007; Alshenqeeti, 2014). Similarly, the use of interviews in this study allowed teachers to be able to interpret, express and negotiate meaning in a natural setting. Interviews also served to provide a platform for teachers to specify the target knowledge for their lessons. Since the knowledge practices were explored from the teachers' perspectives, the target classification had to be determined by them. Semi-structured interviews in combination with video stimulated recall interviews were used, following an interview guide with questions aimed at addressing the first and third research objectives (see *Appendix* D) . The guide provided a structured framework that guided me during data generation to ensure that questions are asked systematically and consistently across all participants. The questions asked were open ended ensuring flexibility in the participants' responses. In addition, open-ended interview questions were used to allow for an in-depth understanding of teachers' perceptions. As argued by Magaldi and Berler (2018) freedom and flexibility are attained using open-ended questions in semi-structured interviews. A broad main question followed by follow up questions and probes were used in the interview process (Roberts, 2020). Teachers were given a great deal of freedom and flexibility when answering the interview questions; for example, if they failed to understand the questions, it would be repeated several times, even in their native language.

Coupling the semi structured interviews with the video stimulated recall interviews enabled teachers to develop a greater awareness of the patterns of engagement that they had with their learners, as well as the thoughts, pictures, and attitudes that elicited their actions or reactions during the lessons (Consuegra et al., 2016). When researchers adopt video stimulated recall in their methodology, participants are shown a previously recorded video of an event that depicts their behaviour to help them recall and interpret past behaviours (Paskins et al., 2017). In a similar manner, teachers were shown a recorded video of their own teaching to help them recall actions or reactions that occurred during the teaching and learning events. This enabled a deeper understanding of teachers' reactions to specific parts of the observed phenomena; teachers were able to interpret, elaborate, and relate their reactions to specific questions asked during the interview.

Audio recordings of semi-structured teacher interviews were used to ensure all participant responses were accurately captured. As argued Rosenthal (2016) this approach minimises distractions associated with manual notetaking and allow for the collection of comprehensive data. Rosenthal further contends that it is impossible for participants to retake an in-depth interview if the data is lost; therefore, it is the researcher's responsibility to choose reliable and secure audio recording devices. Through interviews, teachers were invited to shed light on dynamics and factors that influenced their own teaching. The assumption was that teachers' realities could be uncovered and then interpreted through interactions between the researcher and the participants (Kivunja & Kuyini, 2017).

4.6. Research site, population and sampling

The research took place in a technical science cluster comprising of teachers from technical secondary schools in the Gauteng province of South Africa. These schools fall under Quantile 3 in terms of the Department Basic of Education school classifications. Quantile 3 schools in South Africa are public schools in disadvantaged, middle-income communities that are designated as "no-fee" schools. The overall population consisted of eighteen teachers from technical science schools within the same cluster; however, a sample of eight teachers was selected using expert sampling which a subset of purposive sampling. A sample is a subset of a population chosen for research reasons that is considerably smaller than the entire population (Orihabor & Anyanwu, 2019). Expert sampling involves identifying key informants who can inform an inquiry through their knowledge, experience, and expertise. Experts can provide valuable insights into the root of problems, what has been tried and failed, what has been tried and worked, and future trends to watch (Patton, 2015). It is used to gather insights and understanding from individuals who are considered experts, often during the exploratory phase of research or when specific expertise is crucial. The exploratory nature of this study makes the expert sampling the most fitting method of selecting participants. This study employs two ways of sampling participants: one involves teacher's expert knowledge in the technical sciences content, and the other one involves teachers' proficiencies in using video lessons.

4.6.1. Sampling participants using teacher's expert knowledge in the technical sciences content

Information gathered about teachers revealed that none of them were qualified as technical science teachers, but rather as physical science teachers. This was because technical science was phased introduced in South African schools for the first time in January 2016 in Grade 10 and progressed in grade 11 and 12 progressively in 2017 and 2018. Teachers who were previously teaching physical sciences and had physical sciences teaching qualifications were deemed suitable by the department of basic education to teach technical sciences since these subjects are closely related. To be considered as experts, teachers had to have at least more than three years of experience teaching Technical Sciences, and throughout those years, they should have been teaching Grade 12. This ensured that participants possessed both depth and continuity of subject knowledge in the senior phase, where the complexity of organic chemistry concepts is most pronounced.

As shown in Table 6 below, all eight sampled teachers met these criteria. Their teaching experience in Technical Sciences ranged from three to seven years, with most also having prior experience teaching Physical Sciences for three to thirteen years. This overlap demonstrates a strong disciplinary foundation and practical expertise in related science domains. Additionally, all teachers were currently teaching Grades 10–12, confirming their active engagement with curriculum-aligned senior-level instruction. The combination of disciplinary qualifications, cumulative teaching experience, and consistent involvement in Grade 12 classes validated their inclusion as experts for this study.

Table 6: Teachers profiles based on their subject expertise

Teachers	Gender	Age group	Highest qualification	Subjects of specialisation at tertiary level	Years of teaching physical sciences	Years of teaching Technical Sciences	Overall number years teaching	Subjects allocated at school	Grades taught
Online Teachers									
1	Female	20-25	Honours degree	Life Sciences & Physical Sciences	3	3	3	Technical Sciences & Physical Sciences	10-12
2	Male	25-30	Bachelor's degree	Mathematics & Physical Sciences	3	7	9	Mathematics, Technical Sciences & Physical Sciences	11-12
3	Male	25-30	Masters' degree	Mathematics & Physical Sciences	3	4	6	Mathematics & Technical Sciences	10-12
4	Male	20-25	Honours degree	Life Sciences & Physical Sciences	2	4	4	Physical Sciences & Technical Sciences	10-12
Contact teachers									
5	Male	45- 50	Honours degree	Physical Sciences & Life Sciences	4	7	21	Technical Sciences & Physical Sciences	12
6	Male	30-40	Honour's degree	Mathematics and Physical Sciences	13	7	17	Mathematics, Technical Sciences & Physical Sciences	12
7	Male	45-50	Bachelor's degree	Mathematics and physical sciences	10	6	16	Technical Sciences & Physical Sciences	10-12
8	Male	40-45	Bachelor's degree	Mathematics and physical sciences	6	7	14	Technical Sciences & Physical Sciences	10-12

4.6.2. Sampling participants using teachers' proficiencies in using video lessons

In addition to subject proficiency, the teachers selected for inclusion as the sample for the online sessions were selected based on their computer proficiency. Most of the teachers indicated that they were skilled at video recording their lessons, and some even owned private YouTube educational channels. Since lesson observation took place using contact and online pre-recorded lessons, teachers were requested to identify which method of delivery they were comfortable participating in. From the eight sampled teachers, four were categorised as contact teachers, from which contact lessons would be observed, while four were categorised as online teachers, from whom pre-recorded lessons would be used for lesson observations.

To minimise delays in data collection, online teachers were provided with templates to indicate their proficiencies in using Screencastify and narrated PowerPoint presentations. They were asked verbally if they felt comfortable delivering lessons using these tools. Their responses revealed that although they have some computer proficiency in some respects, their competencies in recording lessons using tools identified had limitations. For example, teachers owning educational YouTube channels explained that the audience was somewhat different, so they indicated that they needed assistance to understand the efficient tools identified as appropriate to produce videos for this study. As a result, an intervention workshop was done for teachers to ensure that they were all proficient with the tools for this study. Table 7 shows teachers' proficiencies in using Screencastify and Table 8 shows teachers proficiencies in using narrated PowerPoint presentations

Table 7: Criteria for rating teachers' proficiency in the use of technology to record videos via Screencastify

Criteria	Description	1 Novice	2 Basic	3 Intermediate	4 Advanced	5 Expert
Video quality	Ability to produce clear, well-lit, and visually appealing videos.	Poor lighting and resolution	Basic lighting, low resolution	Adequate lighting and resolution	Good lighting and high resolution	Professional lighting and resolution
Audio quality	Ability to ensure clear and audible sound in videos.	Poor audio, lots of background noise	Basic audio, some background noise	Clear audio, minimal background noise	High-quality audio, no background noise	Professional audio quality
Editing skills	Proficiency in editing videos to enhance learning.	No editing	Basic editing (cutting, trimming)	Moderate editing (transitions, effects)	Advanced editing (animations, overlays)	Professional editing (complex effects)
Technical setup	Ability to set up and use recording equipment and software effectively.	Struggles with setup	Basic setup skills	Adequate setup and troubleshooting	Proficient setup and troubleshooting	Expert setup, can teach others
Adherence to best practice	Following best practices for video content creation (e.g., length, pace, focus).	No adherence to best practices	Basic understanding	Moderate adherence	Advanced adherence	Expert adherence, sets new standards
Accessibility	Ensuring videos are accessible to all students (e.g., captions, clear visuals).	No accessibility features	Basic features (captions)	Some accessibility features	Comprehensive accessibility features	Highly accessible, innovative approaches

Table 8:Criteria for rating teachers' proficiency in technology for pre-recorded videos (narrated PowerPoint slides)

Criteria	Description	1 Novice	2 Basic	3 Intermediate	4 Advanced	5 Expert
Audio quality	Ability to ensure clear and audible sound in videos.	Poor audio, lots of background noise	Basic audio, some background noise	Clear audio, minimal background noise	High-quality audio, no background noise	Professional audio quality
Editing skills	Proficiency in editing videos to enhance learning.	No editing	Basic editing (cutting, trimming)	Moderate editing (transitions, effects)	Advanced editing (animations, overlays)	Professional editing (complex effects)
Technical setup	Ability to set up and use recording equipment and software effectively.	Struggles with setup	Basic setup skills	Adequate setup and troubleshooting	Proficient setup and troubleshooting	Expert setup, can teach others
Adherence to best practice	Following best practices for video content creation (e.g., length, pace, focus).	No adherence to best practices	Basic understanding	Moderate adherence	Advanced adherence	Expert adherence, sets new standards
Accessibility	Ensuring videos are accessible to all students (e.g., captions, clear visuals).	No accessibility features	Basic features (captions)	Some accessibility features	Comprehensive accessibility features	Highly accessible, innovative approaches
Slide Design	Ability to create visually appealing and well-organised slides.	Cluttered, hard to read	Basic design, some clutter	Clear, organised slides	Well-designed, visually appealing slides	Professional slide design
Narration Quality	Clarity, pacing, and engagement of the narrated content.	Monotonous, unclear	Basic clarity, uneven pacing	Clear, adequate pacing	Engaging, well-paced narration	Highly engaging, dynamic narration
Timing and Synchronisation	Synchronisation of narration with slide content and transitions.	Poor synchronisation	Basic synchronisation	Adequate synchronisation	Good synchronisation	Perfect synchronisation

4.6.3. Online intervention workshops/training

The online workshops were aimed at demonstrating and providing teachers with practical examples that they can adapt to produce the videos. Importantly, this intervention was not implemented as a data-generating activity, but rather as a capacity-building tool to assist teachers in creating the pre-recorded lessons that would later serve as the data source for the study. In other words, the intervention served a facilitative purpose, enabling participants to acquire the necessary technical and pedagogical skills to record effective online lessons. Teachers were given access to three online training sessions through Microsoft Teams, all of which were designed to introduce various strategies to creating online videos. The workshops were conducted online for convenience, as teachers participated after school hours in their convenient spaces. Internet data was provided to the teachers to ensure they had access to the necessary resources for attending the online workshops. They were shown how to use both Screencastify and PowerPoint narrated slides

Figure 8 below is a picture of the online workshop's session conducted to demonstrate to teachers how to record videos for online educational purposes. The example below shows PowerPoint narrated slides where specific functionalities within PowerPoint were emphasised.

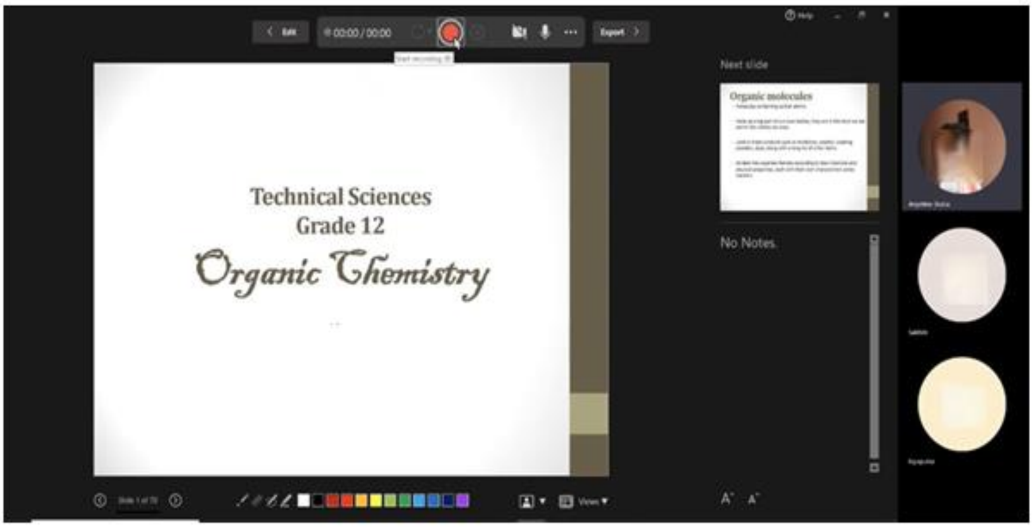


Figure 8: Online workshop session in action

Figure 9 below shows an example of a pre-recorded video produced through Screencastify which is an alternative that teachers could use in producing the pre-recorded videos in this study.

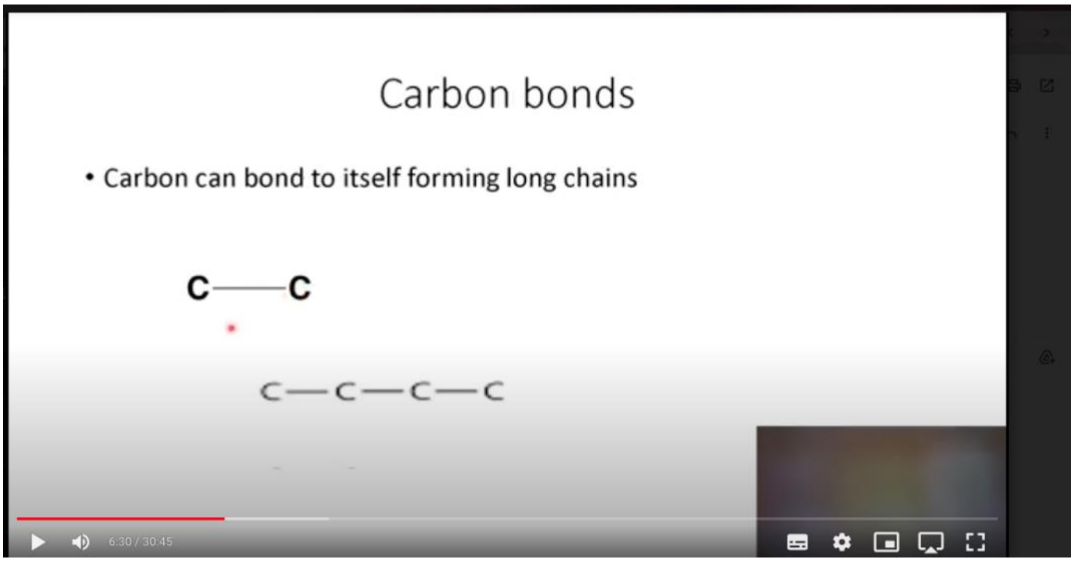


Figure 9: Example of a pre-recorded video recorded through Screencastify

Teachers opted to utilise both narrated PowerPoint slides and Screencastify, which includes all basic recording features for their online lesson observation sessions. An essential component of this study was that teachers were expected to record videos in which they could incorporate audio, a webcam, drawing tools, and other elements required for an online video intended for teaching and learning purposes. It was evident after the training, from teachers, that the workshop helped them to acquire the necessary skills for them to run online lessons, both for the research and for their everyday use.

4.7. Data analysis

According to Soiferman (2010), the philosophical assumptions that underpin the study, as well as the research questions and types of data collected, influence qualitative researchers' choice of analytic methodologies. In any research, one of the most important tasks is data analysis, which requires expert knowledge to handle the data collected according to the project's specified study design. Creswell (2005) contends that knowledge on how to discern text and images is also essential for analysis for the researcher to develop solutions to the study's questions. Creswell adds that qualitative analysis is a continuous process in which inductive and deductive reasoning are alternated. The data analysis process in the study proceeded in six stages shown in figure 8 below and discussed

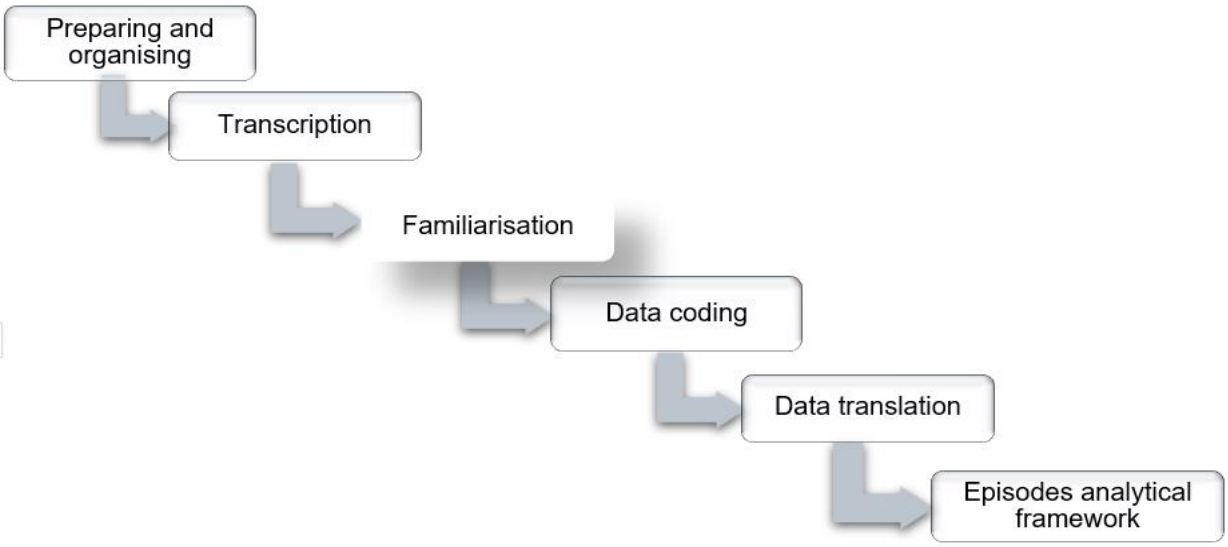


Figure 10: Diagrammatic representation of data analysis stages

Preparing and organising data: During this stage, the collected data was organised in a way that made it manageable to work with. For example, the recorded videos and interviews were arranged in folders, labelled accordingly to avoid mixing up the data. This stage also included reviewing the videos to check for any issues, such as audio quality or corrupt files, that may have occurred during the data recording process. This was done to prepare for transcription.

Transcription: The organised data was then transcribed. The data was transcribed to convert recorded videos and interviews into text, allowing for easier analysis. Simply listening to the recording and assigning codes would have resulted in critical details being omitted. Each lesson transcript was given a code for easy identification and comparisons. The following codes were identified.

Table 9: Codes used to identify teachers in the overall study

Online teachers	**Code**	**Contact teachers**	**Code**
Online teacher 1	OT1	Contact teacher 1	CT1
Online teacher 2	OT2	Contact teacher 2	CT2
Online teacher 3	OT3	Contact teacher 3	CT3
Online teacher 4	OT4	Contact teacher 4	CT4

Additionally, interviews were transcribed to make it easier to identify relevant information from the participants, such as the target content in the lessons they taught. The same codes used to identify teachers were used in interview transcripts as well.

Familiarisation: At this stage, videos were rewatched and the transcription reviewed at least three times to ensure that significant details were not overlooked. Furthermore, documents were reviewed again to make sense of the entire data obtained prior to the coding stage, which is the most important stage in this study. Preparing for the coding stage involved creating a table of associated codes and their meanings. The familiarisation process allowed me to be consistent in assigning positional autonomy (PA) and relational autonomy (RA) codes to specific parts of the data.

Data coding: This stage involves assigning specific codes to specific parts of the transcriptions depending on the associated meanings as observed from the data. For example, when the teacher explained concepts that were core to the topic of organic chemistry, PA++ was assigned. When the purposes or aims carried out during the lesson do not enhance the learning of organic chemistry or school subjects (RA – –) was assigned. Table 10 provides an example of specific coding of data in the topic of organic chemistry within a particular time and explanations of the codes.

Table 10: Example of a coded lesson transcript

Time in the lesson (minutes)	**Description**	**Coding (PA and RA)**
00:00 -05:00	Human beings are made up of carbon. 18% of the human body is made up of carbon. The sugars, the glucose, the protein, and all of those, they're made up of carbon.	Code: PA– , RA – Explanation: Knowledge is derived from biology to explain a chemistry concept,
	These are the valence electrons of carbon. Carbon can form up to a maximum of four points. Focus can be placed on its electron configuration.	Code: PA+, RA+ Explanation: General knowledge regarding science was for teaching organic chemistry
	When a molecule, or when a compound, an organic compound, has only one carbon, it takes a prefix myth.	Code: PA++, RA++ Explanation: Content is on the core component in organic chemistry
	And then carbon, in its natural form, is used in jewellery. Carbon can also be used to make ink and paint.	Code: PA – –; RA– – Explanation: Common or everyday understanding of carbon does not enhance learning of organic chemistry or school subjects.

Translating the data: In this stage, coded lesson transcripts for both online and contact sessions were used to provide explicit instances of each autonomy code. The specific translation device tool outlined in Chapter 3 was useful in this process. This was done to ensure that the coding process demonstrates what was coded and why it was coded in that manner, as well as to show the interconnectedness of the processes. Both coding and translating were done simultaneously, including descriptive interpretations of the coded transcripts. The process of transcribing data utilised two translation devices, one for PA and the other for RA for the overall lesson, then for each episode and then developing autonomy planes for the overall lesson.

Episodes analytical framework: To illustrate the autonomy codes in each lesson, the lessons were divided into episodes depending on the duration. Sorting the lessons into episodes allowed to explicitly specify aspects, such as enactment conditions and, if applicable, the roles of the learners and the teacher, to better understand the knowledge practices employed in both online and contact sessions. Three to four episodes lasting about 10 minutes in each lesson were established for both modes. The table below highlights the layout of the analytical framework which was used for all eight lessons.

Table 11:Example of the layout of an episode analytical framework

Teacher Code	Target knowledge/content	Episodes	Codes enacted	How are the codes enacted	For what purposes	Examples from transcript	Role of teacher	Role of learners	Anything else
CT1									

4.8. Rigour: validity and reliability

Morse et al. (2002) assert that rigour is the strength of the research design and the appropriateness of the method to answer the questions. They argue that it is expected that qualitative studies be conducted with extreme rigour because of the potential of subjectivity that is inherent in this type of research. According to Cypress (2017), qualitative studies are more complicated than other types of studies, and concerns about establishing rigour in qualitative research persist even today.

Qualitative research rigour is associated with the principles of reliability and validity, which are all essential elements of high-quality research (Tappen, 2022). As argued by Cypress (2017) when conducting a study, interpreting findings, and judging the quality of findings, qualitative researchers must be attentive to reliability and validity. According to Brink (1993), in qualitative research, thorough attention to the reliability and validity of studies is especially important because the researcher's perspective may easily obscure the understanding of the findings. As argued by Cypress (2017), without rigour, research is meaningless, becomes fiction, and loses its sense and validity. Researchers should be concerned with answering the following question, according to Lincoln and Guba (1985 in Golafshani, 2003): What can a researcher do to persuade his or her audience that the study findings are reliable or valid? In qualitative research, rigour is concerned with reducing bias while increasing the accuracy and credibility of the findings.

4.8.1. Validity

Validity in qualitative research, according to Leung (2015), refers to the methods, procedures, and data being appropriate. Validity generally determines the accuracy of the methodology, sampling procedure, data analysis procedure, and study findings (Golafshani, 2003). According to Merriam (2005) a valid study must reveal what really exists and depicts reality through accurate means. Merriam adds that a valid instrument must measure what it intends to measure. Validity is crucial in both quantitative and qualitative studies, as argued by Cohen et al. (2007), if a part of the study is deemed invalid, the study is rendered meaningless. Thakur and Chetty (2020) contend that to achieve validity, individuals within a society must agree on how to determine the soundness and accuracy of the study. To maintain validity in this study, available platforms within my institution were used as outlined below:

Wits PhD Weekends: The Wits School of Education normally holds PhD weekends and in these platforms PhD students are required to present their work. Students are assigned two critical readers who engage with their work to provide insightful feedback. During the presentations, the overall audience, comprising academic staff as well as PhD students, are required to add comments relating to the study. Feedback from the presentations were used to align the sample for the study.

Postgraduate Research Authentic Conversations (PRAC): The PRAC is a community of postgraduate students ranging from honours to PhD. In these platforms students present their work and use the feedback to improve on their studies, which was a method used for this study. The suggested feedback resulted in improving particularly the data analysis section, where comments included being clear about how the data is analysed through providing detailed steps relating to the overall data analysis process.

SAARMSTE Research School: This platform utilises academic experts to assist students and emerging researchers to refine their studies/paper. This platform was used to modify the data collection methods for this study.

Writing Retreats: Writing retreats, getaway sessions to focus on modifying research work, were attended to assist in refining this study from its early until the final write up stage. These also operate by assigning mentors who are senior academics and experts in science education research to read and constantly provide feedback of research studies.

LCT Wits community: In addition to above mentioned platforms, I worked closely with experts and students who specifically focus on using Legitimation Code Theory as a framework for their studies. Presenting work in these platforms helped in refining the study analysis and translational devices used. The feedback received in this platform helped in verifying findings through LCT experts.

4.8.2. Reliability

The ability to reproduce findings consistently over time and space is defined as reliability (Souza et al, 2017). The findings of the study must be consistent even when analysed by different observers at different instances. In other words, reliability has to do with the consistency of findings, whereas validity has to do with accuracy of findings. In qualitative research, determining trustworthiness is crucial for ensuring reliability (Golafshani, 2003). According to Cypress (2017), the study should meet the following criteria to ensure that the process is trustworthy: credibility, transferability, dependability, and confirmability.

Credibility: Cypress (2017) defines credibility as an accurate and true depiction of the participants' real-life experiences. To achieve credibility in this study, I examined what was expected and provided a truthful depiction of the participants' social reality (in this case teachers). This was achieved through providing accurate descriptions of how teachers build integrative knowledge in online and contact sessions during their lessons. To clearly show how teachers build knowledge that is integrative in their studies, details were given to teachers on how the data was analysed, enabling readers to assess the whole process' credibility. Using the translation device, this study explicitly provides an account of how the data was coded thus showing the translation between the data and the theory. The data analysis process was explicit as possible thus enabling other researchers to deconstruct or replicate the study. As argued by Ryan et al., (2007) qualitative researchers can show how data analysis was done by disclosing the methods of analysis in enough detail so that readers may establish if the processes carried out in the study are credible. Additionally, the use of several data collection methods such as document analysis, observations and interviews in this study allowed for triangulation. Triangulation combines data from multiple sources to enhance accuracy in data collection and analysis processes (Johnson et al., 2020). For an example in confirming the targets of the lesson observed, document analysis and interviews were used to validate these targets.

Transferability: The potential of the findings to be applied to various contexts or environments is referred to as transferability (Maher et al., 2018). The study includes a detailed description of the research site, background of the participants, including how and why they were chosen for participation in the study. Moreover, the methods and procedures for data collection are explained in detail. Given that the study is qualitative and confined to a specific case, it is critical that I provide a detailed explanation of the research methods and interpretations so that the reader can assess whether it is applicable to their situation or contexts. Furthermore, the LCT translation device used in this study can be adopted or adapted by other researchers to check the consistency of the findings within their contexts.

Dependability: Johnson et al. (2020) states that dependability can be maintained when the researcher explains the methods carried out in the study by giving adequate information which allows for the same work to be repeated by other researchers. In this study, dependability was ensured by providing a detailed description of the research design, data collection methods, and analytical procedures, as well as the rationale behind each methodological choice. A clear audit trail was maintained throughout the research process, documenting each step from participant selection, data generation, and analysis, to the interpretation of findings. For example, the process of lesson observations for both in contact and online settings was systematically guided by a structured observation protocol (*Appendix* F), ensuring uniformity in the way data were recorded and analysed across participants.

Additionally, the online training intervention contributed to dependability by standardising participants' understanding of the tools and processes required to generate the pre-recorded lesson data. Although the intervention did not generate data itself, it ensured consistency in how teachers produced their online lessons, thereby enhancing the reliability and dependability of the data that were ultimately analysed. All teachers received identical guidance and access to resources (including Microsoft Teams workshops and internet data), minimising procedural variations that could compromise dependability. The methodological transparency, detailed documentation, and use of structured instruments (interview and observation protocols) collectively ensured that another researcher could follow the same procedures and achieve consistent outcomes, thus maintaining the study's overall dependability.

Confirmability: For confirmability to be attained, the researcher should highlight that the findings are solely based on information given by the participants rather than the biases and interpretations of the researcher. To adhere to confirmability issues, bias was minimised by permitting LCT scholars to independently analyse the data, thus allowing the same data to be interpreted from different viewpoints. Furthermore, presenting my work in various forums allowed other researchers to scrutinise the findings, limiting potential biases.

4.9. Ethical considerations

Adherence to ethical standards is required to ensure that participants are not exposed to any potential risk or harm and that existing vulnerabilities among research participants are addressed. Ethical clearance to conduct research at the Wits School of Education was obtained (see *Appendix*, A). Permission to conduct research at the schools was first sought from the Department of Basic Education (DBE), which granted approval (see Appendix B). Following this, formal requests were submitted to the principals of the eight participating schools to obtain authorisation to engage with teachers and learners (see Appendix C (i & ii)). Upon receiving consent from all principals, information sheets were provided to the teachers involved in both online and contact sessions, outlining the purpose of the study, the data collection methods, and their rights as participants (see Appendix (iv)). In addition teachers were provided with consent forms so as to have written agreement to participate in the study (see Appendix C (viii & ix)). With the principals' and teachers' permission, learners were then addressed directly to explain the aims and procedures of the study in age-appropriate language. Learners were provided with information sheets (see Appendix C (iii & iv)) to complement the verbal explanation and to share with their parents or guardians. Because all participating learners were under the age of 18, parental consent was required; consent forms were issued to parents or legal guardians for their approval (see Appendix C (vi)). Once parental consent was obtained, learners were given assent forms to confirm their willingness to participate in the study, ensuring that they voluntarily agreed to be part of the research (see Appendix C (vii)).

To maintain anonymity and confidentiality, the participants in the videos (both online and contact sessions) were given pseudonyms, and their faces were blurred to ensure that they are not identifiable. Furthermore, data collected was and is still securely stored in a password-protected computer to ensure that access is only granted to those who are authorised. Finally, in line with ethical research practices, the data obtained in this study will be destroyed 3-5 years after the study is completed.

4.10. Chapter summary

This chapter provided an overview of the study's methodology. The paradigm, research approach, data collection methods, and research sample were explained in detail with their limitations and benefits noted. Additionally, this chapter outlined how reliability and validity were achieved, clearly highlighting the ethical implications related to these aspects. The chapter presented a clear and concise explanation of the data analysis process, where the stages involved were explained in detail to help the readers understand how the researcher achieved the findings of the study. Using the translation device, the chapter explicitly highlighted how the data was translated in this study by showing examples of the coded lesson transcripts from both online and contact lessons. Finally, issues of ethical considerations were addressed, and the study explained how ethics was obtained and adhered to in the overall study. The following chapters will describe the findings of the study, and this will be done on a question-to-question basis to clearly show how the study responds to each research question.

CHAPTER 5: RESULTS AND ANALYSIS

5.1. Introduction

This chapter provides data which was collected to answer the secondary questions used to provide comprehensive data that answered the main research question.

i. How do teachers adhere to the curriculum target knowledge of organic chemistry?
ii. What shift in knowledge structuring patterns are observed when teaching organic chemistry through contact and online sessions?
iii. How can autonomy pathways in online and contact sessions promote the development of integrative knowledge building?
iv. What practices in blended learning environments can promote integrative knowledge building?
v. How can a model for integrative knowledge-building through blended instruction and other supportive frameworks be developed?

Data was arranged according to subtopics derived from these questions and according to the instruments used, then analysed. All data was transcribed and where similar data was collected, it was collated.

5.2. Target knowledge for organic chemistry and teacher compliance

Data to establish target knowledge in organic chemistry was collected through content analysis, individual interviews and lesson observations was used to answer the question: How do teachers adhere to the curriculum target knowledge of organic chemistry?

5.2.1. Target knowledge for on organic chemistry from content analysis

Prescribed content was analysed to establish targets set by the department of education on the content taught using prescribed content in the CAPS document, teachers' year planners as well as learners' books

(i) Target knowledge in the CAPS

The results from the data presented on targets was based on the prescribed content for organic chemistry as stipulated in the CAPS document for examinable Grade 12 Technical science content. This was crucial for this study, to establish the compliance of teachers in the preceding data collection stages. The curriculum document also revealed other aspects affecting teaching and learning such as time taken to cover the content. Furthermore, targets are the primary determinants of autonomy pathways therefore the analysis of the research objectives cannot be accomplished without an explicit account of the target knowledge. Table 12 below outlines target concepts as stipulated through the grade 12 technical sciences curriculum on the topic of organic chemistry.

Table 12: Technical science prescribed content for Organic Chemistry

Organic chemistry topics	**Content, concepts and skills**
1. Organic molecules	• Define organic molecules as molecules containing carbon atoms.
2. Molecular and structural formulae	• Write molecular formulae and structural formulae for organic compounds of up to six carbon atoms for alkanes, alkenes, alkynes, alkyl halides, aldehydes, ketones, alcohols, carboxylic acids, and esters.
3. Functional group	• Define a functional group as an atom or group of atoms that determine the chemistry of a molecule.
4. Homologous series	• Define homologous series as a series of compounds that have the same general formula and where each member differs from the next by -CH2. • Distinguish between different homologous series.
5. Saturated hydrocarbons	• Saturated hydrocarbons contain only single covalent bonds between the carbon atoms.
6. Unsaturated hydrocarbons	• Unsaturated hydrocarbons contain covalent double or triple bonds between the carbon atoms. • Distinguish between saturated and unsaturated homologous series.
7. Isomers	• Organic molecules with the same molecular formula but with different structures are called isomers. • Write structural formulae for given isomers and name the isomers.
8. IUPAC naming and formulae	•Give the IUPAC name when given the formula for alkanes, alkenes, alkynes, alkyl halides, aldehydes, ketones, alcohols, carboxylic acids, and esters. • Give the formula when given the IUPAC name for alkanes, alkenes, alkynes, alkyl halides, aldehydes, ketones, alcohols, carboxylic acids, and esters.

9. Physical properties of organic compounds	• Discuss physical property relationships (boiling point, melting point, vapour pressure, and viscosity) in alkanes, alkenes, alkynes, alkyl halides, aldehydes, ketones, alcohols, carboxylic acids and esters. • Compare the physical properties of different homologous series.
10. Reactions of organic compounds	• Oxidation • Substitution • Addition • Halogenations • Hydrohalogenation • Balance equations for the above reactions using molecular and structural formulae.
11. Plastics and polymers	• Describe the terms polymer, macromolecule, chains, and monomers. • Define plastics and polymers. • Discuss the industrial use of polythene as a basic application of organic chemistry.

Table 12 reveals that there are eleven topics on the topic of organic chemistry prescribed for grade 12 learners. The targets emanating from the curriculum must focus on the concepts mentioned in the policy document, which implies that anything outside of the stipulated concepts, and skills is considered non-target.

(ii) Target knowledge in teachers' year planners

The teachers' guides supplement the CAPS document offering a more detailed plan that guided teachers in lesson planning suggestions, instructional strategies, and additional resources. This guide aims to bridge theory and practice, enabling teachers to deliver lessons effectively and address complex concepts in organic chemistry. These year planners confirmed that teachers' planning documents complied with the prescribed content for Organic Chemistry but were more elaborative. The teachers' targets, observed through the year planners, reflect what learners need to learn; hence, the target purpose is to teach learners these concepts (RA++). The concept map in Figure 11 shows a mind map depicting target topics and their related concepts.

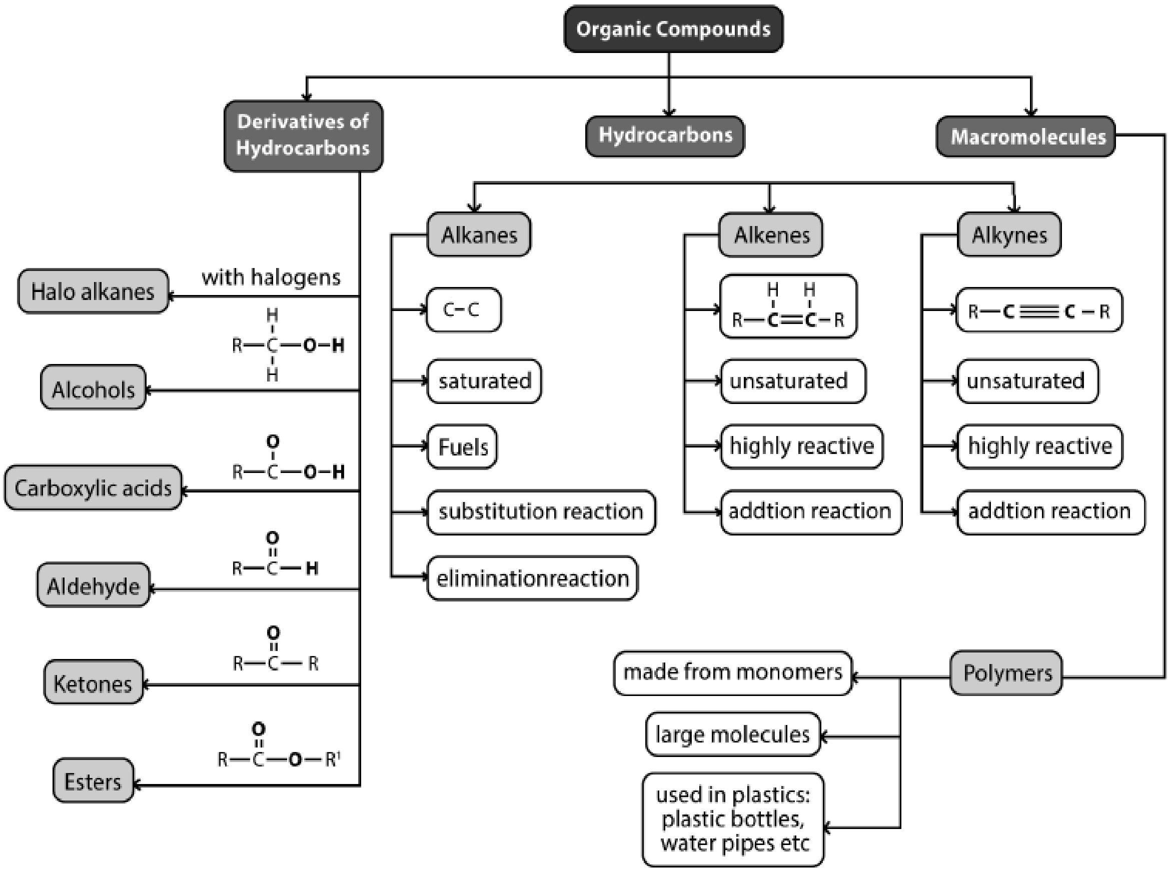


Figure 11: Concept map from the teachers' guide showing concepts to be covered in organic chemistry

(iii) Target knowledge in learners' workbooks

Learners' workbooks were analysed based on compliance with the content prescribed in the CAPS documents as well as teachers year planners, to establish teachers' targets with respect to evidence that content mentioned in these documents had been assessed. Like the CAPS document and teachers' year planners, anything outside of the scope of the topic of organic chemistry in learners' workbooks, was considered non-target content. The Grade 12 technical sciences learners' workbook clearly outlines the concepts in Table 12 below as the key objectives for learners on the topic of organic chemistry.

Table 13: Key objectives from learners' workbooks

Objectives	Content
1	The definition of the term's organic molecule, functional group, homologous series, isomer, polymer, macromolecule, monomer, polymer and plastic.
2	Writing molecular formulae and structural formulae for organic compounds of up to six carbon

	atoms.
3	Distinguishing between different homologous series.
4	Distinguishing between saturated and unsaturated homologous series.
5	Writing structural formulae and names for given isomers.
6	Naming or drawing organic compound structures using IUPAC rules.
7	Discussing physical property relationships in alkanes, alkenes, alkynes, Alkyl halides, Aldehydes, Ketones, Alcohols, carboxylic acids and Esters.
8	Comparing physical properties of different homologous series
9	Balancing equations for specific organic reactions using molecular and structural formulae.
10	Discussing the industrial use of polythene as a basic application of organic chemistry.

Source: Technical Science DBE Grade 12 Learner Book

Observations from both the teacher's year planners and learners' workbooks showed that there was compliance with the CAPS prescribed content. To further verify compliance with targets in the documents observed, lesson observations were done. The translation devise explained in Table 4 and 5, were used to determine autonomy codes related to targets.

5.2.2. Targets confirmed from lesson observations

Lesson observations and pre-recorded observations were done during real time lessons for contact sessions and when videos when produced by teachers for online sessions. Based on the lessons observed for both online and contact sessions, the target knowledge was confirmed based on the teachers' objectives of the lesson from their lesson plans. Observations revealed that teachers were not on the same level of the topic, however these correlated with the prescribed content, teachers' guides and learners' textbooks. Table 14 below shows a summary of target knowledge of all eight (8) observed lessons.

Table 14: Target knowledge from lesson observations

Online teachers	Target content	Contact teachers	Target content
OT1	Introduction to chemistry with specific concepts of homologous series, functional groups, saturated and unsaturated organic molecules	CT1	Introduction to organic chemistry with the focus on the following concepts: molecular and structural formulae, saturated and unsaturated hydrocarbons, homologous series, IUPAC naming and formulae and a brief introduction to isomers
OT2	Introduction to organic chemistry with specific concepts of IUPAC naming	CT2	Basic introduction to organic chemistry with the key concepts: organic molecules definition, molecular and structural formula, saturated and unsaturated hydrocarbons and IUPAC naming and formulae
OT3	Molecular formula, Saturated and unsaturated organic molecules, homologous series, functional group and isomers.	CT3	Physical properties of organic compounds
OT4	Introduction to organic chemistry with focus on the following concepts: molecular structures, IUPAC naming and formulae (alkanes), saturated and unsaturated compounds and homologous series	CT4	The concept of isomers

Table 14 shows that the set targets correlate to the expected content for grade 12 learners as seen in the curriculum documents. What further sets these targets apart is the focus on whether the lesson is an introduction or a carryover. For example, six teachers specified through specific phrases that their lessons were introductory lessons (OT1, OT2, OT3, OT4, as well as CT1 and CT2), whereas two teachers appear to have introduced the topic already and were focused on concepts such as physical properties, which seem to be the final concepts based on the sequence of the content from the CAPS document (CT3 and CT4). Although the specific content focus varied across lessons, this variation does not detract from the comparability of the lessons, as all topics fall under the broader theme of organic chemistry. The key concern of the study was not the particular sub-topic addressed, but how teachers structured and enacted knowledge-building processes within the broader disciplinary context. In this sense, differences in content sequence merely reflect the natural progression of teaching within the

CAPS framework rather than fundamental differences in pedagogical intent or conceptual focus.

According to the translation device, when a teacher explains ideas emanating from the prescribed concepts, this is associated with PA++ as an autonomy code, while PA+ will speak to other topics in the technical sciences curriculum that are not entirely the target but are used for the purposes of learning about the target. PA− and PA− − will be ideas that are entirely outside of the technical sciences that's considered non-target in this study. From lesson observed, the target knowledge (PA++) as specified by the teachers was knowledge from the technical science curriculum with the specific focus on the topic of organic chemistry, while the target purpose (RA++) was to deepen understanding of that topic.

5.2.3. Targets confirmed through interviews

Individual interviews were conducted with teachers to determine their perceptions of targets for their lessons. To establish the understanding of teachers' perspectives of targets based on their lessons, they were asked what the purpose/focus/aim of the lesson was, and their responses are captured in Table 15.

Table 15: Summary of targets confirmed through interviews

ONLINE TEACHERS	
OT1	"The lesson aimed to develop learners' conceptual understanding of what organic chemistry is. It was an introduction lesson to organic chemistry, focusing on homologous series: alkane, alkene,"
OT2	"IUPAC naming is one of the key concepts in organic chemistry, my focus was on that, of course, in the process, I would touch on other concepts that complement this. for an example, by default I will have to speak of homologous series and structural formulae because they form part of IUPAC naming if you think of it."
OT3	"I wanted learners to understand molecular and structural formulas by the end of this lesson. I am not sure if this was achieved, but that was my aim. Also, key definitions of functional groups, saturated and unsaturated carbons, as well as what homologous series are, were the priority for me."
OT4	"The main aim of the lesson was to introduce learners to organic chemistry. In simple terms, I had aimed to make students aware of the terminologies, organic structures, and the rules for naming organic compounds used in this science topic."
CONTACT TEACHERS	
CT1	"Because this was an introductory, I was just beginning to introduce a chapter on organic chemistry, my focus was introductory topics as sequenced in the CAPS"
CT2	"My focus was for them to understand definitions of organic molecules and draw molecular and structural formulas; again, I wanted them to know about the saturation of compounds, it is also important for them to know IUPAC naming and its' rules."

CT3	"Today my focus was on physical properties."
CT4	"This was a very short lesson on isomers and physical properties of organic molecules; my aim is simple."

The target knowledge confirmed by the teachers during interviews corresponds to the curriculum documents as well as the lesson observations analysed in terms of key objectives articulated during instruction. The exception is with OT2, whose objectives are listed as IUPAC naming; however, when questioned about the target knowledge, the teacher revealed other concepts that, according to him, are part of the IUPAC naming comprehension package. This explicitly emphasises the significance of validating targets, as they may not be immediately evident but require confirmation from teachers.

From the eleven (11) subtopics under organic chemistry identified as targets through documents, the concepts of organic reactions, as well as plastic and polymers, were not confirmed as targets in the lessons delivered by the teachers, for both online and contact lessons based on lesson observations and interviews. The confirmed targets were influenced by various factors that shaped how the lessons unfolded. For example, six of the eight teachers noted that the lessons were in the introductory phase, while others mentioned that the lessons were carryover lessons. As a result, the focus of lessons was influenced by these differences. Based on the above analysis, it is possible to conclude lessons taught by teachers that were focused on introducing the topic of organic chemistry were at a conceptual level rather than an application level. From the observations and interview responses, there was no revelation of non-targets which includes everyday concepts or concepts from other topics besides organic chemistry.

5.3. Shift in knowledge structuring patterns when teaching organic chemistry

This section provided data necessary to answer the secondary question: *What shift in knowledge structuring patterns are observed when teaching organic chemistry through contact and online sessions?*

The data presented uncovered shifts in knowledge patterns observed during organic chemistry lessons. Eight lessons (four contact and four online) were analysed and interpreted to gain insight into the learning processes that shaped how the codes were mapped on the autonomy plane. Each lesson was subdivided into episodes to capture the progression of events over time without losing crucial details. Depending on the duration of the lesson, there were three to four episodes in each lesson, with each episode lasting approximately ten (10) minutes. Dividing lessons into episodes was a critical analytical approach as it allows for the clear mapping of the knowledge patterns, conditions leading to such patterns, and practices from teachers that contribute to the structure of the patterns. The findings in each lesson are therefore structured to develop chronologically based on the identified episodes. Individual contact and online lessons were observed, interpreted, awarded appropriate positional and relational autonomy codes using translational devices, then autonomy planes for each lesson were presented to create a visual map of how the lesson progressed.

5.3.1. Observations made from contact sessions

5.3.1.1. Observations made from contact lessons of CT1

The objectives of this lesson were to introduce learners to the topic of organic chemistry. The teacher focused on the concepts of molecular and structural formulae, saturated and unsaturated hydrocarbons, homologous series, IUPAC naming and formulae, and a brief introduction to isomers. The lesson was approximately 40 minutes from which 4 episodes were developed.

(i) Translation device and episode analytical framework for CT1

The translation device illustrates examples used to establish positional and relational autonomy strengths that emerged in the entire lesson (Table 16) then autonomy codes enacted in the overall lesson for each episode (Table 17).

Table 16: Positional and Relational autonomy translational device for CT 1 lesson analysis

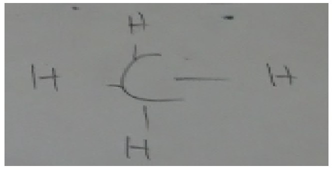
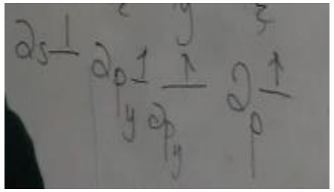
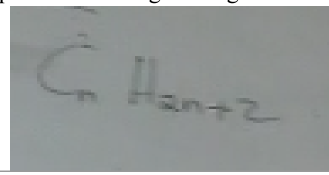
Strength	Codes (PA and RA)	1st Level Indicator	2nd Level indicator	Specific examples for CT1 lesson
Stronger ↑	PA++, RA++	Target content and purpose	The teacher describes ideas from the topic of organic chemistry with the purposes of deepening understanding of the topic	What I have drawn here is called an organic molecule (referring to methane structure below).  In organic molecules, we have what is called hydrocarbons. What are hydrocarbons? Hydrocarbons—I think it is self-explanatory. Hydrocarbons? Molecules that have hydrogen and carbon.
	PA+, RA+		The teacher focuses on ideas that are not from organic chemistry but from the technical science curriculum in general. The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.	Then, under high temperature, this proton is going to get excited (referring to proton on 2s). It's going to come here. We have 2s1, 2px1, 2py1, and 2pz1. 
	PA−, RA−	Non-Target content and purpose	Teachers uses ideas that are academic but are outside of the technical science curriculum and the purposes speak to other domains that are not unique to understanding organic chemistry	***No PA is noted in the lesson; however, there are examples of non-target purposes in the lesson.*** So, it's two multiplied by 5 plus 2. Referring to the general formula. 
↓ Weaker	PA− −, RA − −		The teacher explains ideas that are not linked to any school subjects; thus, the purposes do not enhance learning of organic chemistry/any school subjects	None observed.

Table 17: Codes observed in relation to the lesson episodes

Episode	Codes enacted	Code Name	For what purposes?	Role of learners in each episode.
1	PA+, RA+	Sovereign	Introduce the prerequisite concepts and basic periodic table skills	- To demonstrate readiness for learning by settling down and maintaining silence as instructed. - Use periodic table skills to look up for elements. - Asking Questions
	PA++, RA++	Sovereign	Consolidate understanding	
	PA+, RA+	Sovereign	Conceptual linking	
	PA++, RA++	Sovereign	Deepen understanding	
	PA+, RA+	Sovereign	Linking concepts (e.g methane and the nature of carbon)	
2	PA+, RA+	Sovereign	Conceptual linking	- Paying attention - Engage with content through drawing structural formulas and responding to questions - Asking questions.
	PA++, RA++	Sovereign	Deepen understanding	
	PA++, RA−	Projected	Mathematical linking	
3	PA++, RA++	Sovereign	Deepen understanding	- Pose questions to the teacher encouraging detailed explanations from the teacher
	PA+, RA+	Sovereign	Consolidate understanding	
	PA++, RA++	Sovereign	Deepen understanding	
4	PA++, RA++	Sovereign	Deepen understanding	- Engaging with content - demonstrate reactions that indicate lack of understanding
	PA+, RA+	Sovereign	Consolidate understanding	
	PA++, RA++	Sovereign	Deepen understanding	

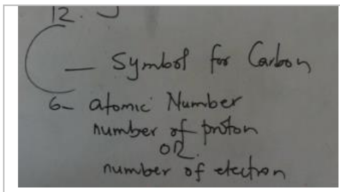
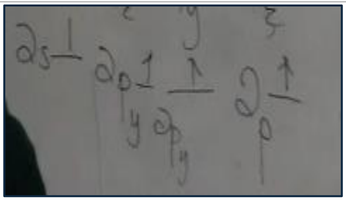
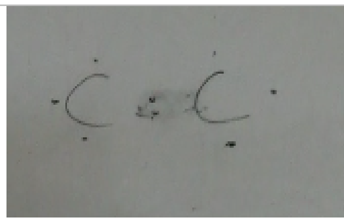
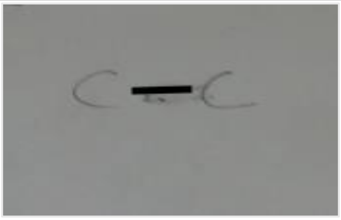
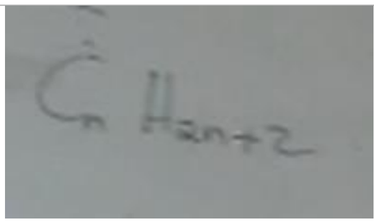
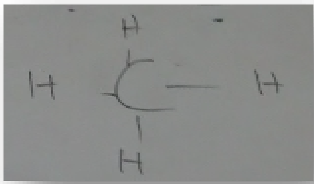
A comparison of the content taught by CT1 confirmed that the target was sequenced in the CAPS document. From the translation device, it was established that the teacher manages to tap into the following codes: PA++, PA+, and RA++, RA+, RA−; however, no specific examples in the lesson emanated from PA− −, RA− − and PA−. Throughout the lesson the teacher did not include the exotic codes, implying that ideas that are not linked to any school subject (PA− −) or ideas borrowing knowledge from other domains (PA−) and purposes that do not enhance the learning of organic chemistry (RA− −) were not explored in this lesson. While the translational device aids in highlighting specific examples from the lesson, it does not reveal clearly the shifts in codes made by the teacher in the overall lesson.

To visually illustrate the shifts in autonomy codes made by CT1, it was important to fully understand the autonomy codes opted for in the overall lesson in relation to the lesson episodes. Table 16 highlights the codes enacted in each episode, the conditions for the enactment of these codes, as well as the role of the learners during the lesson. Contact sessions entail interactions between the teacher and learners; hence, it is critical to highlight the role of the learners in defining the general atmosphere of the lesson. A specific instance occurred in this lesson when a learner asked a question on semiconductors that had nothing to do with the organic chemistry, and the teacher politely refused to answer the question, explaining why. This act alone guaranteed that the teacher remained on target. Specific teacher-learner interactions somewhat influenced the codes enacted. Interpretations of each episode are discussed below.

(ii) Individual lesson analysis for CT1

Episode 1

The lesson began with the teacher focusing on introducing general science ideas (PA+), with emphasis placed on the concept of the periodic table, electron configuration, and covalent bonding of carbon element. While this is prior knowledge from previous grades, it is necessary for the teacher to touch on this knowledge as it lays the foundation for the learning of organic chemistry as a topic. The introduction of these prior concepts implies an intentional use of knowledge from other topics within the technical science curriculum to learn about organic chemistry (RA+). At this point in the lesson, PA and RA were slightly stronger. A series of shifts from slightly stronger autonomy (PA+, RA+) to stronger autonomy (PA++, RA++) was observed as the lesson progressed. These shifts allowed the teacher to consolidate understanding of the introduced concepts, clearly showing how they related to the target content and purpose. Throughout this episode, the teacher used diagrams to enhance understanding, thus further strengthening relational autonomy (PA). Learners asked questions, consulted their periodic table to respond to questions, while the teacher focused on behaviour, instructing them to maintain order.

Diagrams above illustrated properties of the carbon element from the periodic table, electron configuration, covalent bonding, valence electrons, molecular and structural formula of methane.

Episode 2

Following a shift from PA+ and RA+, in this episode the teacher spent roughly six minutes out of 10 within stronger positional and relational autonomy (PA++, RA++). Learners were given a task in which they were required to draw structural formulas, which is part of the target content and skills. Throughout the process, the teacher guided learners to connect ideas between the target concepts and other science knowledge to build a deeper understanding of the target concept. At the same time, there were interactions between the teacher and the learners where learners negotiated for meaning based on the task at hand. A shift from PA++ and RA++ to PA++ and RA- was observed. The teacher weakened relational autonomy (RA) by shifting from the sovereign code to the projected code. Within the projected code, the focus was on procedures that were borrowed from mathematics to explain the general formula of organic molecules. Mathematical multiplication and addition procedures were used to explain how the formula works. Mathematical procedures served as a support structure for learning organic chemistry concepts, hence RA-. The extract below shows real interaction between the teacher and learners during the lesson.

TEACHER: *Now guys, look at this (referring to the general formula provided). This is the formula.*

LEARNERS: *Formula for what?*

TEACHER: *We can use it to determine the number of hydrogens and carbons. Alright, let's use it. Now, let's say we have 7 carbons. Pay attention! We have 7 carbons, so the number of hydrogens is going to be 7 multiplied by 2, which is going to be?*

LEARNERS: *14.*

TEACHER: *Plus 2?*

LEARNERS: *16*

The extract above highlights the use of multiplication and addition to come up with a general understanding of the number of carbons of heptane, which is an organic molecule made up of 7 carbons using the general formula. The was a shift from sovereign codes to projected codes. However, when learners were taught to use the structural formulae to identify the IUPAC name of an organic compound, they only utilised scientific skills, hence this was purely procedures. Such procedures remained as RA++ instead of RA- since they constitute aims existing within the science curriculum to deepen understanding of science concepts. The extract below seeks to demonstrate this distinction.

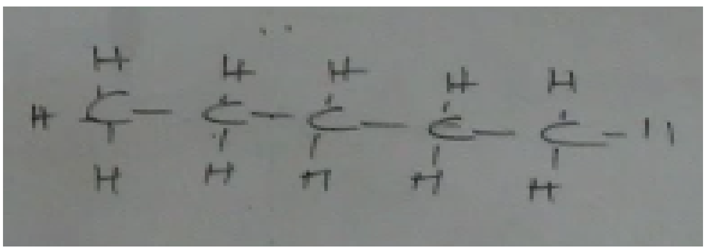
TEACHER: *Okay, let's do it again. One, two, three, four (counting carbons for butane). Check: you must be observant! The carbon in the middle will only have two hydrogens. And then the one at the end will have how many?*

LEARNERS: *Three.*

TEACHER: *Okay. That is your butane. Now let us look at pentane, pentyl. Remember, it has to do with 5. So how many carbons do we have here?*

LEARNERS: *5 carbons*

TEACHER: *1, 2, 3, 4, 5 (drawing the structure of pentane as shown below). The middle carbon only has two hydrogens. The valence of carbon is still how many?*

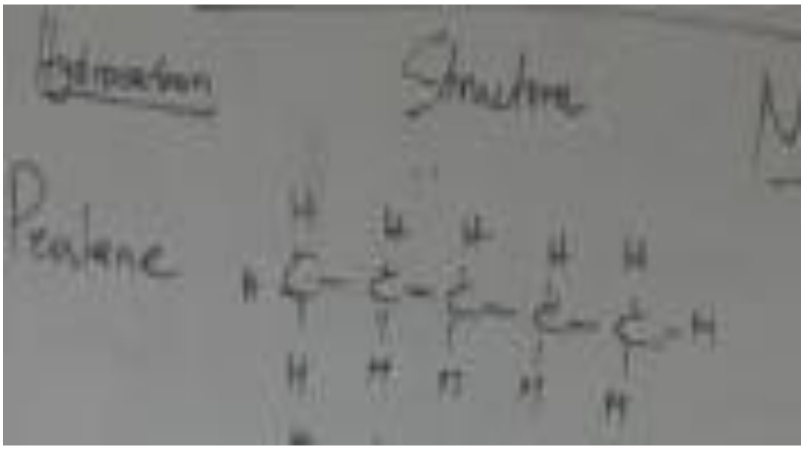


Based on the above extract, counting the number of carbons is an IUPAC naming rule, which is part of the science skills that learners are required to master to understand the naming of organic molecules. The teacher also mentions that pentane has to do with 5, which is mathematics knowledge of shapes. However, in this case, this is not entirely borrowed knowledge because prefixes for identifying organic compounds based on the IUPAC nomenclature follow a similar conversion.

Episodes 3 and 4

Episodes 3 and 4 constitute 20 minutes from the overall lesson. In these episodes the teacher made shifts between slightly stronger to stronger positional and relational autonomy and vice versa. Like the rest of the episodes, PA++ and RA++ codes serve the purpose of deepening understanding of the target content, whereas PA+ and RA+ codes were enacted for the purposes of consolidating understanding. The extract below highlights such instances.

TEACHER: *What do we mean by saturated hydrocarbons? Pay attention, guys! Saturated means the carbon here (referring to pentane structure below)*



There's only a single bond. Where? Between the carbons. Not the hydrogens. Between the carbons! There's a single bond between the carbons.

***LEARNERS**:* *So, what is this bond?*

TEACHER: *There's a single bond. One bond here (showing the line between carbons). There's only one electron.*

LEARNERS: *One electron.?*

TEACHER: *Yes! So, remember, the carbon is able to bond with itself. It can use this vacant space. Remember I told you that it's vacant spaces? There are four electrons on the outside. These four electrons can be used. It can form a single bond using* *one electron. It can use two electrons, forming a double bond. Now coming to what's called a double bond.*

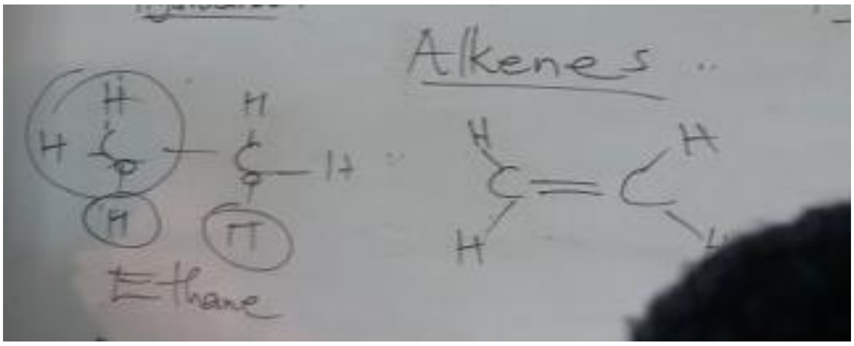
We have unsaturated hydrocarbons. Do you see this? This one is saturated (referring to all previous examples). So, there's no space for another double bond for carbon.

The concept of saturated hydrocarbons was the target content, and diagrams were used to deepen understanding (PA++, RA++). The mention of the nature of carbon and its bonding related to general knowledge of science for the purposes of learning organic chemistry (PA+, RA+), then a shift back to the target content of saturated and unsaturated is explained clearly linking concepts (PA++, RA++). Overall, until the end of the lesson, there was a slight weakening and strengthening of PA and RA, but this occurs within one code, the sovereign code.

Throughout the lesson, the teacher enforces discipline, and learners raised questions. Some of the questions presented by learners assist the teacher focus on the target. For example, when learners were being disruptive and the teacher spent an extensive amount of time reprimanding them, the lesson quickly transformed into a life coaching session, which, while necessary at times, can interrupt the main lesson. The life coaching sessions proceeded until one of the learners posed a question about the topic at hand, which allowed the teacher to shift the focus back to the target content.

Additionally, as the lesson proceeds, the learners' reactions revealed a lack of understanding of the concepts. At this point, learners and the teacher negotiate meaning, and the teacher explains concepts in response to their expressions of confusion. The scenario from these episodes underscores the importance of contact interactions, as learners' expressions may influence the overall dynamics of the lesson. To clarify the concepts, the teacher constantly switched from PA++, RA++, and PA+, RA+, and vice versa. Positional and relational autonomy are gradually weakened and strengthened until common ground is reached. With PA++, RA++ understanding is deepened, whereas with PA+, RA+ understanding was consolidated. The extract below depicts such an interaction.

TEACHER: *One, two (The teacher emphasises that the double bond is already counted as two bonds), three, four, including the other hydrogens on the first carbon (as shown on ethene structure below)*



LEARNERS: *Five, six (they continue counting number of hydrogens)*

TEACHER: *No, man, where are you getting the five?*

LEARNERS: *I thought we were counting everything*

TEACHER: *I mean around the first carbon, the number of bonds around this carbon (referring to the first carbon on ethene) is one, two, three, four. They don't exceed four. The bonds here: how many? (Teacher draws a structure of methane as an example.)*

LEARNERS: *Four.*

TEACHER: *They don't exceed four!*

LEARNERS: *Does this mean there are four electrons?*

TEACHER: *I am talking about bonds; bonds and electrons are not the same. Now listen, let's continue again. This is our ethene; let's look at the molecular formula there. How many carbons are there?*

LEARNERS: *Two*

TEACHER: *C2 (writing the first part of the formula), how many hydrogens?*

LEARNERS: *Four*

TEACHER: *H4 (teachers complete the formula on the board)*

OTHER LEARNERS: *No. 6, 4, 6*

TEACHER: *But we are talking about this structure here (pointing to ethene). Where is the six coming from?*

LEARNERS: *mumble a lot at this point as they seem to be discussing the number of carbons...*

TEACHER: *Let me try and explain it much better. Guys, this is going to be deep chemistry, but I will try and explain it.*

From this point onwards, the teacher explained the concept of valence electrons and covalent bonding (PA+, RA+) as these concepts appear to be concepts hindering comprehension. The concepts explained were then linked to target content. This reveals that weakening positional and relational autonomy creates an entry point for learners to understand the target concepts. The teacher's explanation leads back to the target content as the lesson concludes with the teacher reconciling understanding. Throughout the lesson, the teacher weakens and strengthens positional and relational autonomy within the sovereign code. The autonomy plane below visually maps the autonomy codes enacted in the lesson, indicating the shifts made by the CT1 throughout the lesson.

(iii) Autonomy plane for CT1 lesson analysis

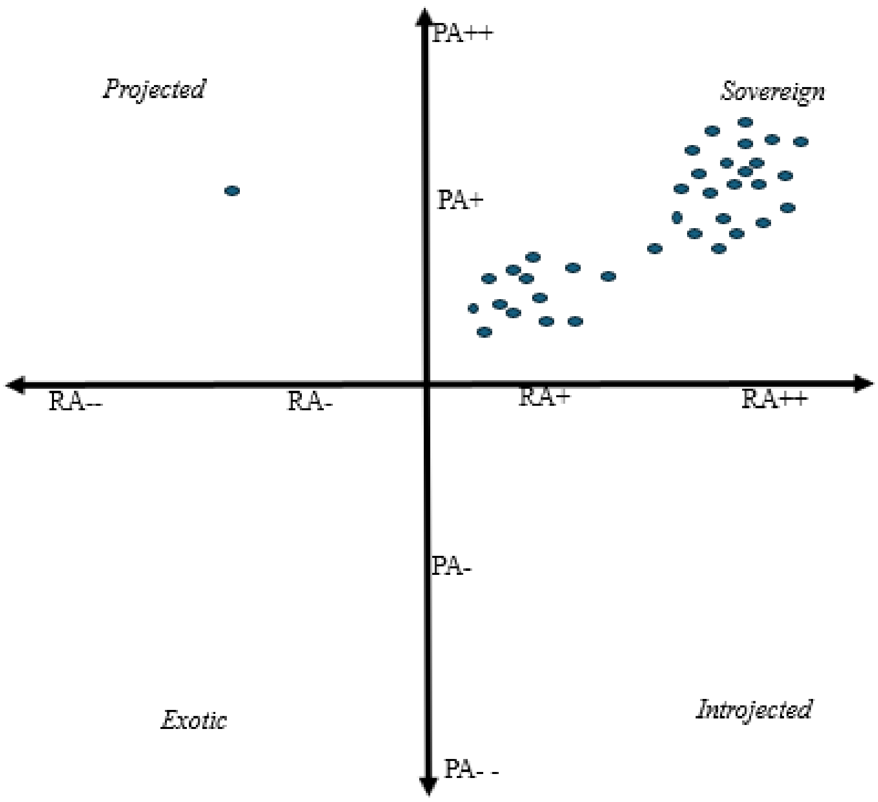


Figure 12: CT1 Autonomy plane

Following the detailed analysis of the CT1 lesson, it is notable that the teacher spent a significant amount of time on the sovereign code, with one instance observed where there is a shift to the projected code (refer to the autonomy plane above). This means that most explanations, examples, and ideas presented during the lesson emanated from the topic of organic chemistry as prescribed in the technical science curriculum and were introduced for the purposes and aims of deepening understanding of the topic.

The challenge presented by the approach opted for by CT1 in this lesson was that knowledge remained segmented with rigid adherence to science-specific practices, which risk isolating scientific concepts from other disciplines or real-world applications. Drifting to the projected code was necessary but limited, and the teacher did not draw knowledge from the exotic and introjected codes at all. While the sovereign code grounds science in its disciplinary identity, overstaying within it limits the potential for integrative knowledge building experiences that arise from connecting and integrating knowledge across domains. An intentional, dynamic interplay between codes can help address this limitation, fostering a richer, more integrated understanding of science and its broader applications.

5.3.1.2. Observations made from contact lessons of CT2

This lesson was approximately 40 minutes long, with 4 episodes each lasting 10 minutes. The teacher focused on the definition of organic molecules, molecular and structural formulas, saturated and unsaturated hydrocarbons, as well as IUPAC naming.

(i) Translation device and episode analytical framework for CT2

The teacher described this lesson as a basic introduction to organic chemistry. The translation device in Table 18 below demonstrates specific examples for each level of positional autonomy and relational autonomy that the teacher taps on during the entire lesson. Table 19 shows autonomy codes enacted in each episode.

Table 18: Positional and Relational autonomy translational device for contact teacher 2 lesson analysis

Strength	Codes (PA and RA)	1st Level Indicator	2nd Level indicator	Specific examples for CT2 lesson
Stronger	PA++, RA++	Target content and purpose	The teacher describes ideas from the topic of organic chemistry with the purposes of deepening understanding of the topic	The question was, how do we distinguish between methyl and ethyl? Methyl has got what? One carbon. Remember it's supposed to be methane, but we took one hydrogen, so it becomes? An Alkyl!
	PA+, RA+		The teacher focuses on ideas that are not from organic chemistry but from the technical science curriculum in general. The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.	Carbon has four valence electrons. What do you mean by that? If these are valence electrons, these are electrons that are taking part where? In a chemical reaction. So therefore, it says that carbon is the element that will form four bonds around itself.
	PA− , RA−	Non-Target content and purpose	Teachers uses ideas that are academic but are outside of the technical science curriculum and the purposes speak to other domains that are not unique to understanding organic chemistry	What happens? We remove another hydrogen. From where? And then you end up having the cations. This is what we call catenation. We talk about this in physical science.
Weaker	PA− −, RA − −		The teacher explains ideas that are not linked to any school subjects; thus, the purposes do not enhance learning of organic chemistry/any school subjects	This is where your take is. To name the molecule or the structure, you get three marks. So, you get a mark for allocating the branches? And then you get one for identifying the branches, which are the methyl's. Okay? And then you get one for naming the parent.

Table 19: Codes observed in relation to the lesson episodes

Episode	Codes enacted	Code Name	For what purposes?	Role of learners in each episode.
1	PA− −, RA− −	Exotic	To introduce organic chemistry from an everyday point of understanding	- Learners respond to questions. - Learners required to maintain order.
	PA+, RA+	Sovereign	Introduction of pre-requisite concepts	
	PA++, RA++	Sovereign	Deepen understanding	
	PA− −, RA++	Introjected	Linking common understanding to target content	
	PA++, RA++	Sovereign	deepen understanding	
	PA− −, RA++	Introjected	Linking common understanding to target content	
	PA++, RA++	Sovereign	Deepening understanding	
2	PA++, RA++	Sovereign	Deepen understanding	- Learners respond to and ask questions.
	PA+, RA+	Sovereign	Conceptual linking	
	PA++, RA++	Sovereign	Deepen understanding	
	PA− , RA−	Exotic	Extending knowledge	
	PA++, RA++	Sovereign	Deepen understanding	
3	PA++, RA++	Sovereign	Deepen understanding	- Probe questions. - Respond to questions. - Express confusion through mumbling and facial expressions. - maintain order.
	PA− −, RA++	Introjected	Linking common understanding to target content	
	PA++, RA++	Sovereign	Deepen understanding	
	PA− −, RA++	Introjected	Common understanding to consolidate meaning	
	PA++, RA++	Sovereign	Deepen understanding	
4	PA++, RA++	Sovereign	Deepen understanding	- Respond to questions. - Collective rectification of mistakes.
	PA++, RA− −	Projected	Assessment	
	PA++, RA++	Sovereign	Consolidating and deepening understanding	

Based on the translation device in Table 17 the teacher was able to explain concepts using ideas that range from the topic of organic chemistry (PA++) to everyday understanding (PA−−). In terms of the aims and purposes, the teacher managed to focus on purposes of deepening understanding (RA++) to purposes that do not enhance the teaching of any school subject (RA−−). In this lesson, the teacher was able to focus on all levels of target content and purpose. Table 18 highlighted the specific codes enacted per episode, revealing the shifts in autonomy codes made by the teacher during the overall lesson. From table 18, it is evident that the teacher was able to shift between all four codes: sovereign (PA++, RA++) and (PA+, RA+), exotic (PA−−, RA−−), introjected codes (PA−−, RA++) and projected (PA++, RA−−). This implies that the target content and purposes, as well as non-target content and purposes, were touched on depending on the conditions of enactment and the role played by the learners in the overall lesson. How these shifts were made possible in the overall lesson is explained in terms of episodes in the following interpretation.

(ii) Individual lesson analysis for CT2

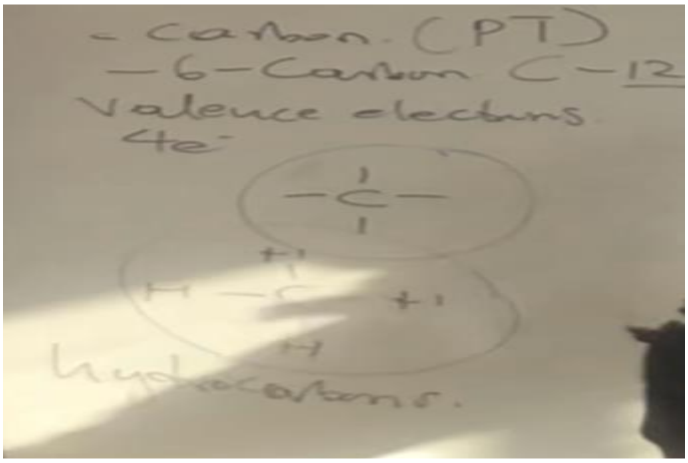
Episode 1

The lesson began with weaker positional and relational autonomy (PA− −, RA− −) with the teacher introducing the general concept of organic chemistry. To introduce the topic, the teacher asked learners why it is important to study organic chemistry. This question laid a foundation for explanations that leads the lesson further from the target content and purpose. The teacher explained that organic foods are supposedly healthy and then touched on why people would rather opt for organic foods. At this point in the lesson, the focus had entirely shifted from organic molecules (target content) to organic foods and food preferences (non-target). Organic foods is common knowledge that learners may even bring to the learning context. The purposes of the lesson therefore deviate from the target purpose (deepening understanding of organic chemistry, RA++) to focus on healthy eating habits, which is further away from the target purpose, hence RA−−.

It appears that this explanation was necessary, as it created conditions for the teacher to be able to link everyday knowledge to the target content and purpose. The teacher asked, "*Why is organic milk organic*?" and learners responded by stating that it contains carbon-containing molecules. From here a shift from exotic codes (PA−−, RA−−) to the sovereign codes (PA+, RA+) is noted. The teacher uses the learners' responses to introduce carbon as the building block of all materials and further explains in terms of the nature of carbon why organic molecules contain carbon. Similar to CT1, the concepts of the periodic table, valence electrons, and covalent bonding of carbon are explained as a means to help learners conceptualise the relevance of carbon in this lesson. Doing so allows the teacher to tap into general knowledge of science (PA+), which is introduced with the aim of enhancing understanding of the topic of organic chemistry (RA+).

The shift to PA+ and RA+ created an entry point to the introduction of the target content as the teacher explains a simple hydrocarbon (methane), which occurs as a result of one carbon molecule bonding with four hydrogen atoms. This explanation allows the teacher to shift to PA++ and RA++ as the explanations focus on the target content (ideas from the topic of organic chemistry), with the diagrams serving the purpose of deepening understanding of the topic. The introduction of the methane structure enables the teacher to delve into the concept of saturated and unsaturated hydrocarbons as well as IUPAC naming, both of which are target concepts. Learners, on the other hand, appear to be familiar with these concepts as they were reciting the naming of simple structures (see extract below). The teacher later explained during the interview that organic chemistry is first introduced in grade 11, and part of his teaching strategies include scaffolding based on prior knowledge to build on what they already know. Even so, this knowledge remains PA++ and RA++ because the teacher validated it as part of his target. The extract below highlights this instance.

TEACHER: *Now, this is a simple molecule (referring to the structure below). What determines these structures? You will have to go from basic structures. The alkanes. So, the alkanes are characterised by what?*



LEARNERS: *By the single bond.*

TEACHER: *And then, if the bond is single, is that saturated or unsaturated?*

LEARNERS: *Saturated.*

TEACHER: *What do we mean by saturated?*

LEARNERS: *Because it contains single bonds.*

TEACHER: *It contains single bonds! Hence, we are saying it is saturated. If it is having a double or triple, then it is?*

LEARNERS: *Unsaturated.*

TEACHER: *Unsaturated! Now, these molecules will differ because of the number of carbon atoms. Now, as you go further, you say one carbon. One carbon is what? Methane. And then two carbons? Ethane. Three carbons?*

LEARNERS: *Propane.*

TEACHER: *And then four carbons?*

LEARNERS: *Butane.*

TEACHER: *And then five carbons?*

LEARNERS: *Pentane*

TEACHER: *(drawing these structures on the board) So that's pentane. And then one, two, three, four, five, six. So, this is six carbons (drawing the structure of hexane on the board). So, it becomes?*

LEARNERS: *Hexane.*

From this point, the teacher weakened positional autonomy (PA− −) while relational autonomy remained stronger (RA++). This is seen when the teacher intentionally uses everyday examples to explain IUPAC naming, which later leads to the concept of functional groups (PA++). Everyday examples in this case are introduced to deepen understanding of the target content through an intentional link between knowledge from outside the classroom with the purposes of teaching classroom knowledge. See extract below.

TEACHER: *Now, the name of these hydrocarbons, like your name, you've got your name, and then you've got your surname. So, we have the prefix. Okay? And then we have what's called a suffix. So, in other words, the prefix is your name, the first name, and then your suffix is your surname. So, we say these are all what? Alkanes (referring to all the mentioned structures). That means they've got the same surname, but they differ in what? In the number of carbon atoms. Yes, their names, but they are all what? Alkanes. That means an alkane is what? It's a functional group.*

Understanding that is left only at PA− − presents problems of segmented learning in which learners may struggle to link everyday understanding to the scientific concepts being taught. Following the weakening of PA, the teacher then strengthened positional autonomy once again by explaining that prefixes and suffixes change depending on the number of carbons, and this defines the functional group; a shift from PA− − to PA++ is then observed. Before strengthening positional autonomy, the teacher signalled this to the learners by stating that "*we are now going to dive deeper into the chemistry concepts*". This episode thus highlights the intentional shifts between PA and RA codes over time in the lesson. Learners in this episode are required to respond to the questions posed, and this assists the teacher in determining whether PA or RA needs to be weakened and strengthened.

Episode 2

The focus in this episode is IUPAC naming and its rules. This is part of the target content as identified by the teacher (PA++), and the strategic explanations of IUPAC naming rules define the target purposes as the teacher is focused on deepening understanding of organic chemistry. The teacher emphasised that when naming compounds, learners should first determine the number of carbons and then determine which carbons form the longest chain. These rules are necessary for learners to grasp as they are designed to enhance understanding of the topic of organic chemistry; hence, this scenario is coded RA++. Thus, the beginning of this episode illustrates a scenario in which the teacher is immersed within the sovereign code (PA++, RA++).

Over time in the lesson, the teacher slightly weakened PA and RA by revisiting the concept of carbon bonding, thus shifting to PA+ and RA+. The focus on the nature of carbon reinforces foundational knowledge from other topics (identified as prior knowledge from previous grades in technical sciences curriculum), which is important for understanding the concept of functional groups. Explanations for several functional groups such as alkanes, alkenes, and alkynes and how to identify them are provided; throughout the process, learners asked the teacher questions and responded to the questions from the teacher. This enabled the teacher to strengthen PA and RA again by switching back to PA++ and RA++, since these explanations are part of the target content. The series of weakening and strengthening of PA and RA creates a dynamic learning context that allows learners to see how general science concepts link with the target content.

The explanations relating to alkynes as a functional group led the teacher into introducing and explaining the concept of catenation. This concept is further away from the target content as it emanates from the physical sciences curriculum. The teacher also made it clear to the learners that the concept is further elaborated on in the physical sciences (see extract below). The brief introduction of the concept of catenation created a shift from PA++ and RA++ (sovereign code) to PA− and RA− (exotic code). This implies a shift from the target content and purposes to non-target content and purposes. Shifting to exotic code is necessary as it emphasises the interconnectedness of knowledge across domains, potentially enhancing integrative knowledge practices.

TEACHER: *What I want us to do is just grab the basics. Now, triple bonds. What happens? We remove another hydrogen. From where? And then you end up having the cations. This is what we call catenation. We talk about this in physical sciences. For now, we will just say this is a radical. It means it needs somewhere to go. It's negative. It's looking for a partner. Yes. Now, what happens in your structure?*

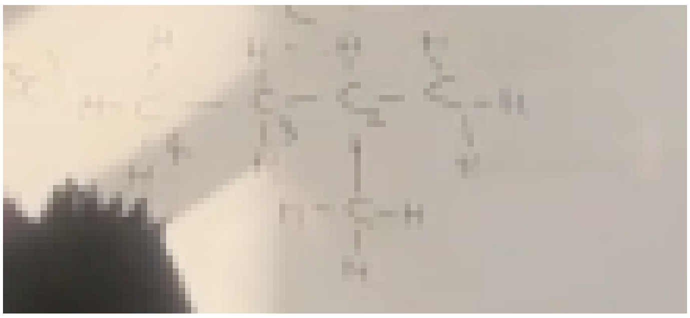
The extract above highlights the weakening of PA and RA, and the concepts introduced serve as extended knowledge. As previously stated, such a shift is necessary to demonstrate to learners that disciplines, particularly the technical and physical sciences, are not entirely isolated. However, the teacher stresses in the post-interview that it is important for teachers with a background in physical sciences to limit their explanations of physical science concepts since this is technical science. This is particularly true since too much focus can detract from the primary target; thus, transitioning to exotic codes should be brief and purposeful. Furthermore, the clear recognition of catenation as a concept of the physical sciences curriculum acts as a border marker to draw attention back to the target content. Following this shift, the teacher strengthened autonomy by shifting back to PA++ and RA++. The remainder of the episode is then characterised by this shift in which the teacher and the learners engaged in unpacking the concept of IUPAC naming, molecular, and structural formulas, with the teacher drawing these structures to help learners create mental images.

Episode 3

The episode began with PA++ and RA++, which is a continuation of the ideas explained towards the end of episode two. The teacher was focused on explaining IUPAC naming with a special focus on the rules of conversion; additionally, focus was placed on naming branched hydrocarbons. All these concepts form part of the target content (PA++) since they touch on molecular structures and IUPAC naming, which the teacher confirmed as part of the target content. Diagrams are used to anchor and deepen understanding of the target content, hence denoted as RA++. In the process, explanations are well scaffolded, and active participation from learners is noted as they respond to questions posed. At the beginning of this episode, stronger PA and RA is noted; however, a shift is observed as the teacher greatly weakens positional autonomy only to PA− −. Doing so allows for a shift from the sovereign code (PA++, RA++) to introjected code (PA− −, RA++). Within the introjected code, the teacher is focusing on using everyday examples to effectively explain the naming of hydrocarbons when a side chain is presented.

The weakening of positional autonomy serves as a deliberate pedagogical strategy that helps bridge the gap between abstract or complex scientific concepts of IUPAC naming and forms of knowledge that learners are familiar with, thus embracing relevance in the science classroom. The incorporation of everyday knowledge is aimed at deepening understanding of the target content; hence, RA remains stronger (RA++). The extract below clearly illustrates how the teacher made shifts from PA++ and RA++ (sovereign code) to PA− − and RA++ (introjected code).

TEACHER: *Okay, a branch. This is a branch (referring to the CH3 branch below). But we have what? The longest chain. So, we've got to be specific. Where is this branch? And what do we call this branch? And at which carbon? So, you first say, at carbon 2, I've got this branch. What is this branch?*



LEARNERS: *It's methyl.*

TEACHER: *It's methyl because it contains one carbon. And then, as you go from your longest chain, it's your surname. How many carbons are there?*

LEARNERS: *Four.*

TEACHER: *So, it becomes what?*

LEARNERS: *It becomes butane.*

TEACHER: *Butane, okay? So now, when you name this, you must be specific, okay? Remember, whoever is not on the longest chain is aside. So, you don't consider. These are just abomzala (a Zulu word referring to cousins); they are just relatives. And we know the surname.*

LEARNERS*:* *They are cousins! (referring to the side chain)*

TEACHER*:* *Cousins yes! So where is methyl? So, the name would be 2-methyl. What is the surname?*

LEARNERS: *4-methylbutane.*

TEACHER: *No, because we know. We don't put that 4. We know there's 4 carbons. So, if there's 4 carbons, it is butane. So, it's 2-methylbutane.*

From the above extract, it remains clear that the concept of *abomzala*, a Zulu word for cousins, is introduced with the aim of simplifying the abstract concept of branching in organic chemistry. Following this example, the teacher directly linked the everyday understanding of the concept of branching to the target content, where learners were required to determine the name of the molecule in the diagram above. Linking the analogy to the target content enables the teacher to shift from PA− − to PA++ signalling a return to discipline-specific discourse. The purposes remain those of deepening understanding of organic chemistry (RA++); thus, a shift from PA− − and RA++ back to PA++ and RA++ is noted.

Following the shift to the target content, learners are required to identify the name of the molecule in the above diagram to which they responded with 4-methylbutane instead of 2-methylbutane. The teacher detects a lack of understanding by facial expressions, a sense of unease in the classroom, and questions from a few learners. This prompted the weakening of PA, again a shift from PA++ to PA− − is noted, in which the teacher opted for different forms of everyday knowledge to further illustrate the concept of branching. The intentional weakening of positional autonomy allows learning to be grounded in familiar practices, thus increasing the potential for integrative knowledge building. In the extract below, intentional conversion of methyl to *Sipho* and butane to *Ngobese* (a Zulu surname) is used to help learners make explicit links between the target concept and everyday knowledge.

TEACHER: *You are lost? Where is methyl? At carbon 2? What is the longest chain giving us?*

How many carbons are here? (referring to the structure above)

LEARNERS: *Four.*

TEACHER: *So, it becomes what?*

LEARNERS: *Butane.*

TEACHER: *And then where is methyl? At carbon 2? So, the name of this becomes what? 2-methylbutane.*

LEARNERS: *So, what about this carbon?*

TEACHER: *2 is the location. If you see any number, if you see any number in the molecule, it means it is specific; there is somebody there. There is somebody there. Something is happening there. Where? At carbon 2. Who is there?*

LEARNERS: *Methyl.*

TEACHER: *So, methyl is Sipho, butane (Ngobese). And Sipho is what? The cousin! (The cousin refers to the side chain or branch, as already mentioned from the first extract in this episode.)*

The ability of the teacher to weaken PA as a result of learners' expression illustrates how the teacher prioritises learner-centred knowledge building. Furthermore, the teachers' immediate response to learners' reactions underscores the advantages of contact sessions (Špehte, 2021), as real-time feedback cues allow the teacher to adjust strategies as needed. Following the shift to PA− −, understanding is not left grounded in everyday knowledge, but a return to PA++ is observed. The diversion to everyday knowledge was intentional, serving to scaffold understanding of the target content. For the remainder of this episode, the teacher and learners focus on naming branched hydrocarbons; complex examples involving two side chains are also discussed; all of this occurs within the sovereign code (PA++, RA++), and diagrams are used to anchor explanations.

Episode 4

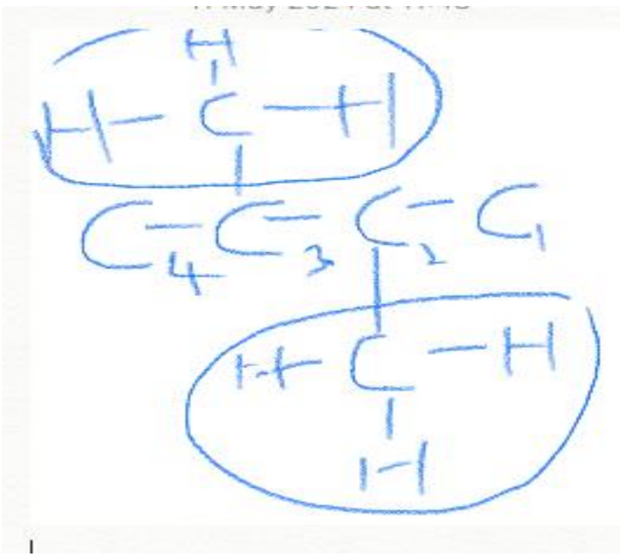
The episode began with the teacher explaining ideas from the topic of organic as prescribed from the technical science curriculum (PA++) for the purposes of enhancing understanding of the topic (RA++). In this episode, a shift to PA++ and RA-- is noted; this occurrence allowed the teacher to shift between all the codes in the overall lesson. Within this code, the teacher further discussed the target content (PA++); however, the content is explained in relation to purposes that do not enhance direct learning of organic chemistry as the focus is on assessment strategies. This is understandable given that the lesson is designed for grade 12 learners who will be sitting for their final year-end examinations; thus, the balance between teaching organic chemistry concepts and equipping learners with assessment-related strategies is a necessity. See extract below.

TEACHER: *How many methyl's do we have? Two. What does di mean?*

LEARNERS: *Double.*

TEACHER: *And then where are these methyl's situated?*

LEARNERS: *Carbon two and three. So, what is the name now?* ***Referring to the structure below.***



TEACHER: *2,3 dimethylbutane! This is where you take is. To name the molecule or the structure, you get three marks. So, you get a mark for allocating where the branches are? And then you get one for identifying the branches, which are the methyl's. Okay. And then you get one for naming the parent. In a situation where you don't know the location, but you know that there is di. For the fact that you know there's di, and then you identify the longest chain, butane. You get one mark* *for butane; you will not forfeit. So, we are looking for a way and means for you to get marks.*

While aligning the lesson to RA − − ensures that learners acquire assessment techniques, delving too much into this code can risk promoting route learning. Fortunately, in this lesson, a learners' question allowed the teacher to shift focus from exam preparation to the target content and purposes, enabling a return to RA++. At this instance, the learner identified a mistake in the structure drawn by the teacher on the board. Collectively, the teacher and the learners rectified this mistake; this allowed the teacher to clarify and reinforce concepts within the sovereign code (PA++, RA++) until the end of the lesson. The teachers' ability to shift from PA++ and RA− − (projected) to PA++ and RA++ (sovereign) allowed for a pedagogic framework that supports learning of target ideas (PA++) while embracing the scientific inherent values (RA++). In addition, this shift helped in maintaining a balance between exam readiness and fostering transferable understanding of organic chemistry.

(iii) Autonomy plane for CT2 lesson analysis

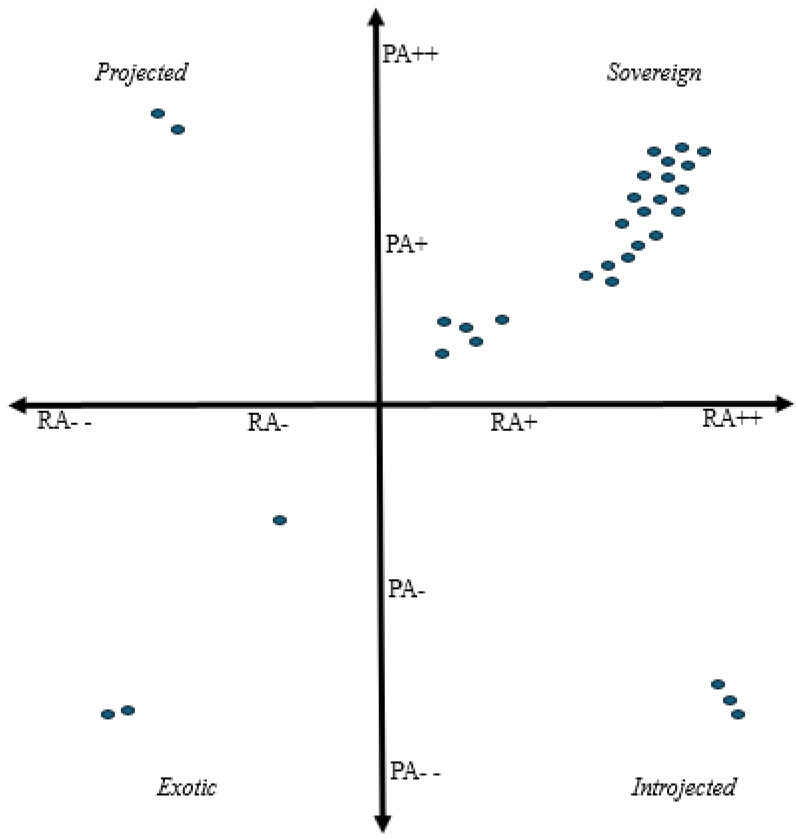


Figure 13: CT2 Autonomy plane

The autonomy plane above illustrates that CT2's lesson transitioned across all four autonomy codes: exotic, sovereign, introjected, and projected codes, respectively. This implies that the teaching practices in this lesson focuses on ideas that emanate from the technical science curriculum for the purposes of deepening understanding of organic chemistry (sovereign) to non-target content and purposes that explain ideas from everyday knowledge (exotic), then non-target ideas introduced to deepen understanding of the overall learning (introjected), and finally ideas that focus on target content with purposes that do not directly enhance the learning of the topic (projected). Shifting to all four codes in the lesson is necessary as it enables the teacher to draw from diverse sources of knowledge. Doing so establishes the groundwork for multidisciplinary understanding of science concepts.

The teacher predominately spends time in the sovereign quadrant, where the focus is on specialised scientific knowledge (PA++, PA+) that is relevant to the science domain (RA++, RA+). Spending time in this quadrant guarantees that learners get a solid understanding of science concepts, which is critical since the purpose of any instruction in any subject is to get learners to comprehend the discipline's concepts and procedures. As seen from the plane, the teacher is however able to deliberately shift through different codes (exotic, introjected, and projected), with less time spent in each. This can be interpreted as the teacher leaving the science home in search of relevant knowledge needed to help learners understand the science concepts.

These shifts enable integrative knowledge building as the teacher is able to modify teaching practices to respond to learners' conceptual needs. Moreover, observed shifts between all four codes highlight the teacher's flexibility in terms of how pedagogy is approached. This is necessary for addressing challenges such as knowledge blindness, essentialism, and segmentation, as highlighted by Maton and Howard (2018). For example, the teacher's deliberate effort to infuse knowledge from diverse sources in the lesson prevents issues of knowledge blindness. Furthermore, adapting pedagogy to respond to learners needs highlights that knowledge practices are changeable rather than fixed, thus essentialism is challenged. Finally, the shifts between target and non-target content and purposes allow learners to connect various sources of knowledge, addressing the issue of segmented learning. For example, when the teacher activated learners' prior knowledge or drew on their everyday experiences to introduce or explain a concept, they created meaningful entry points that help learners relate new information to what they already know. This movement between familiar and disciplinary knowledge enables learners to recognise patterns, make conceptual connections, and build coherence across ideas. Such pedagogical actions are effective for knowledge building because they bridge every day and scientific ways of knowing, allowing the teacher to move fluidly between common understandings and domain-related knowledge while expanding the knowledge base for learners.

5.3.1.3. Observations made from contact lessons of CT3

The target content of this lesson was the physical properties of organic compounds, with the target purpose of deepening understanding of the topic. The lesson was approximately 45 minutes with 4 episodes. Unlike lessons for CT1 and CT2, this was not an introductory lesson, as physical properties in the technical science curriculum are covered towards the end of the overall topic of organic chemistry.

(i) Translation device and episode analytical framework for CT3

Specific examples, as observed in the lesson, are presented on the translational device below for both positional autonomy and relational autonomy. The translation device in Table 20 below demonstrates specific examples for each level of positional autonomy and relational autonomy that the teacher taps on during the entire lesson. Table 21 shows autonomy code enacted in each episode.

Table 20: Positional and Relational autonomy translational device for contact teacher 3 lesson analysis

Strength	Codes (PA and RA)	1st Level Indicator	2nd Level indicator	Specific examples for CT3 lesson
Stronger	PA++, RA++	Target content and purpose	The teacher describes ideas from the topic of organic chemistry with the purposes of deepening understanding of the topic	So, we are basically talking about the four physical properties. The boiling temperature or boiling point, the melting point, the vapor pressure, and the viscosity of organic molecules.
	PA+, RA+		The teacher focuses on ideas that are not from organic chemistry but from the technical science curriculum in general. The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.	Because the electron negativity is too high, we are saying which atom is going to attract electrons that are being shared in the covalent bonding.
	PA− , RA−	Non-Target content and purpose	Teachers uses ideas that are academic but are outside of the technical science curriculum and the purposes speak to other domains that are not unique to understanding organic chemistry	None observed.
Weaker	PA− −, RA − −		The teacher explains ideas that are not linked to any school subjects; thus, the purposes do not enhance learning of organic chemistry/any school subjects	None observed.

The translation device highlights the ability of the teacher to draw on ideas that describe the target content (PA++) to deepen understanding of the topic (RA++). Throughout the lesson, the teacher was able to slightly weaken positional autonomy and relational autonomy by focusing on ideas that do not emanate directly from the topic of organic chemistry but are general science concepts from the technical sciences curriculum (PA+). These concepts are introduced for the purposes of drawing from other topics to learn about organic chemistry (RA+). Notably, the lesson does not draw from non-target content and purposes, as none were observed in the overall lesson. This means that the codes PA− and RA− as well as PA− − and RA− − remain unaddressed. The table below illustrates the codes enacted in relation to episodes identified in the lesson.

Table 21: Codes observed in relation to the lesson episodes

Episode	Codes enacted	Code Name	For what purposes?	Role of learners in each episode.
1	PA++, RA++	Sovereign	Introducing key ideas, e.g. functional groups	- Note taking - Paying attention - Respond to questions
	PA+, RA+	Sovereign	Consolidate understanding	
	PA++, RA++	Sovereign	Deepen understanding	
2	PA++, RA++	Sovereign	Deepen understanding	- Note taking
	PA+, RA+	Sovereign	Consolidate understanding	
	PA++, RA ++	Projected	Consolidate understanding	
3	PA++, RA++	Sovereign	Deepen understanding	- Note taking - Respond to questions with yes or no responses.
	PA++, RA++	Sovereign	Deepen understanding	
	PA+, RA+	Sovereign	Consolidate understanding	
4	PA++, RA++	Sovereign	Deepen understanding	- Class activity - Pay attention - Note taking
	PA+, RA+	Sovereign	Consolidate understanding	
	PA++, RA++	Sovereign	Deepen understanding	

(ii) Individual lesson analysis for CT3

In all the episodes identified in the lesson, the teacher stays within the sovereign codes where positional autonomy and relational autonomy are slightly weakened and strengthened over time in the lesson. The teacher thus shifts between PA++, RA++, and PA+, RA+, and vice versa to deepen or consolidate understanding. Following this observation, it can be concluded that the entire lesson focused on specialised science knowledge and purposes, with no opportunities for the teacher to venture elsewhere to source for knowledge necessary to help learners understand organic chemistry. The role of the learners in this lesson is mostly limited to note-taking and behavioural focus (the teacher frequently reminds learners to maintain silence). A detailed interpretation of the lesson is given below. Since the same codes are noted in all 4 episodes with no significant shifts, the analysis of this lesson will focus on the overall lesson rather than on individual episodes to avoid redundancy.

In the entire 45 minutes, the teacher remained within the sovereign code (PA++, RA++ and PA+, RA+) where positional autonomy and relational autonomy are slightly weakened and strengthened over time, depending on the conditions and dynamics of the lesson. For example, the lesson began on stronger positional autonomy and relational autonomy (PA++, RA++), where the teacher introduced the concept of a functional group, which appeared to be an integral concept in this lesson. See extract below.

TEACHER: *Functional group. What is a functional group?*

LEARNER: *Functional group………. **[inaudible]** it seems the learner is talking about isomers*

TEACHER ***:*** *No, no, no, no, I am not talking about isomers. I am talking about the functional group.*

LEARNERS: *An atom…a group of atoms that determines the chemistry of a molecule.*

TEACHER: *The chemistry of a molecule! And when we talk about the chemistry of a molecule, what are we referring to? What is the chemistry of a molecule?*

LEARNERS: [inaudible]

TEACHER*:* *The atoms inside the molecule? We have been defining the functional group for a while now. Look at the definitions! The definitions that we have for the definition of a functional group. I think you can guess the definition. What does it say?*

LEARNERS AND THE TEACHER: *An atom or group of molecules that determines the physical and chemical properties of a molecule.*

TEACHER *That is the part that I was interested in. A functional group is an atom or a group of atoms that determines the physical and chemical properties of a molecule or of a group of organic compounds. Okay? So, today we want to talk about the physical properties of organic compounds.*

From the extract, the concept of a functional group is then linked to molecules. Introducing molecules slightly weakens positional autonomy and relational autonomy (PA+, RA+), as the concept is a general science concept within the technical science curriculum that is often taught at lower grades. Understanding does not only remain at PA+ and RA+; the teacher then strengthens PA and RA, leading to a shift towards PA++, RA++. At this stage, the concept of a molecule is revisited, and the teacher specifies that the definition is not complete without an inclusion of chemical and physical properties. This further establishes the basis for introducing physical properties, which is the target content for this lesson. Within this framework, the teacher elaborated on types of physical properties, and general science concepts such as intermolecular forces, covalent bonding, electron negativities, and the distinction between polar and nonpolar molecules are incorporated as the lesson progresses. Throughout the lesson, there is a continual series of weakening and strengthening of PA and RA, presenting an interplay between PA++, RA++, and PA+, RA+. To help create visual representations, diagrams are also introduced and anchored by explanations in the lesson.

In this lesson, there are missed opportunities for incorporating knowledge from other sources since the teacher primarily draws from practices within the technical science curriculum. By focusing exclusively on practices that deepen understanding of science-specific targets (sovereign codes), the lesson limits learners' exposure to broader contexts. While the focus on the sovereign codes ensures that learners are grounded within the technical science curriculum, which is necessary as it aligns with the targets; however, it limits the opportunities for learners to be familiarised with non-target content and purposes that are necessary to provide an integrative understanding of organic chemistry. Thus, not diversifying to other codes, for example, exotic codes (PA− − , RA− − or PA−, RA−) limits the potential to enrich learners understanding of science concepts through interdisciplinary connections or a pedagogy grounded on what learners bring to the classroom.

In the entire lesson, the role of the learners is predominately passive, as the primary role is taking notes and responding with yes and no answers, which indicate low engagements with the content. There is, however, one instance in the lesson noted at episode 4 (seen in table 16) where learners were involved in a class activity; this activity was not consolidated, as discussions emanating from it were not evident. The limited engagement combined with the teacher-centred approach in this lesson played a huge role in constraining shifts in autonomy codes. The teacher did not fully leverage the potential of contact session interactions to inform the practices enacted in the lesson. As noted in the CT2 lesson, learners' responses and expressions can create a possibility for shifts between different codes in the lessons.

(iii) Autonomy plane for CT3 lesson Analysis

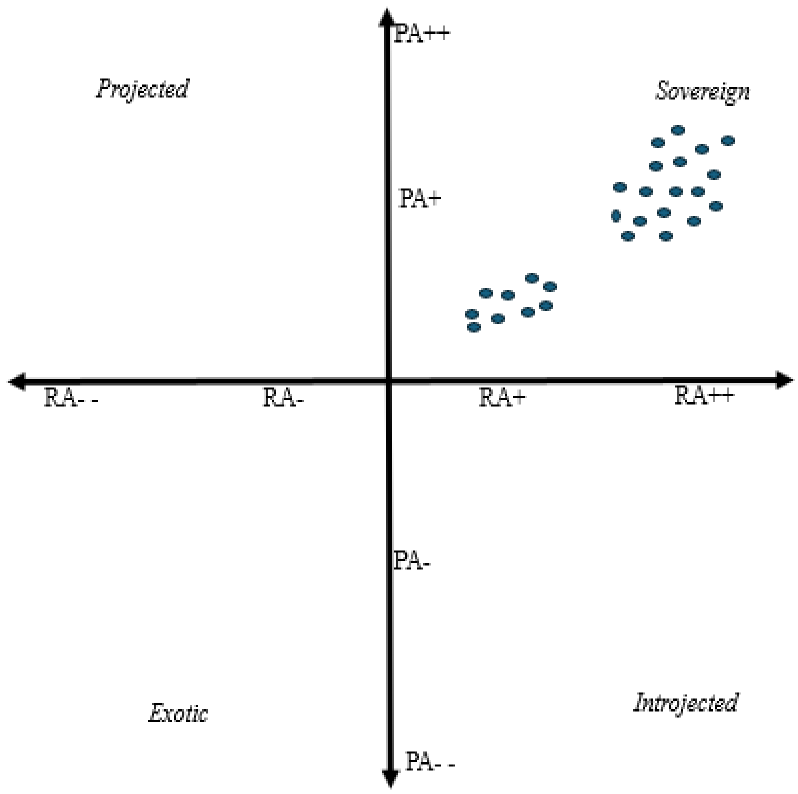


Figure 14: CT3 Autonomy plane

The autonomy plane above visually represents the autonomy codes enacted in the CT3 lesson. The clustering of the dots in the sovereign quadrant indicates a predominant focus on targets, which highlights the focus on enforcing science ideas. The lesson predominantly revolved around ideas from organic chemistry as prescribed through the technical sciences curriculum

(PA++) for the purposes of deepening overall understanding of the topic (RA++). However, the teacher managed to slightly weaken PA and RA continuously throughout the lesson. This weakening of autonomy indicates the ability of the teacher to allow for connections between the target content and related science concepts. This entails a focus on general knowledge regarding science (PA+), for the purposes of consolidating understanding to enhance overall learning of organic chemistry (RA+). Even though the shifts are noted, these shifts remained within target content or purposes boundaries, which in essence still prioritise the scientific disciplinary knowledge. The plane further indicates the absence of knowledge forms emanating from the projected (PA++, RA- -), introjected (PA−− , RA++) and exotic codes (PA−− , RA−−). This indicates no engagement with knowledge from everyday understandings or wider interdisciplinary links, which is necessary for integrative knowledge building to occur. CT3 lesson did not offer opportunities for exploring knowledge beyond the core curriculum and this constrains integrative knowledge building.

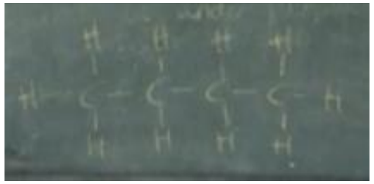
5.3.1.4. Observations made from contact lessons of CT4

This lesson was 30 minutes long with a total of 3 episodes and focused on the concept of isomers as confirmed by the teacher. The lesson was a carryover from the previous lesson, which briefly introduced the general definition of isomers. The aim of this lesson was then to deepen understanding of the concept of isomers through specifically focusing on drawing structural formulas, naming as well as identifying the types of isomers.

(i) Translation device and episode analytical framework for CT4

A significant amount of time in the lesson involved learners' being hands-on through the drawing of structural formulas, which required them to be actively engaged during the overall lesson. Specific examples of positional and relational autonomy as observed in the lesson are highlighted in the translational device in Table 22 and then the autonomy codes enacted in each episode in Table 23 below.

Table 22: Positional and Relational autonomy translational device for contact teacher 4 (CT4) lesson analysis

Strength	**Codes (PA and RA)**	**1st Level Indicator**	**2nd Level indicator**	**Specific examples for CT4 lesson**
Stronger ↑	PA++, RA++	Target content and purpose	The teacher describes ideas from the topic of organic chemistry with the purposes of deepening understanding of the topic	Alright, now it's the exact same formula there. How many hydrogens do we have here? 10, right? How many carbons? 
	PA+, RA+		The teacher focuses on ideas that are not from organic chemistry but from the technical science curriculum in general. The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.	It can be either an atom, a group of atoms, or a bond, remember?
	PA−, RA−	Non-Target content and purpose	Teachers uses ideas that are academic but are outside of the technical science curriculum and the purposes speak to other domains that are not unique to understanding organic chemistry	Cn, n here is 4, nhe? There is n… H, right? 2n plus 2, so it's 4. 2 times 4 is 8. Plus 2 is what? It's 10? So which homologous series does that one belongs to? ***(The above example pertains only to RA−)***
↓ Weaker	PA− −, RA − −		The teacher explains ideas that are not linked to any school subjects; thus, the purposes do not enhance learning of organic chemistry/any school subjects	So, this type of question you only get in question 2. When you open your question paper, you have multiple choices; you go to question 2, and you get this type of question. ***The above example pertains only to RA- since the purposes are for assessment.***

From the table above, it is notable that the teacher managed to tap into all the codes except PA− and PA− −, as examples related to these codes were not evident in the lesson. This absence suggests that non-target content, which includes ideas that are not related to any school subject (everyday knowledge), and ideas emanating from other disciplines were not explored in the overall lesson. The table below highlights the specific codes enacted per episode, revealing the shifts in autonomy codes made by the teacher during the overall lesson.

Table 23: Codes observed in relation to the lesson episodes

Episode	Codes enacted	Code Name	For what purposes?	Role of learners in each episode.
1	PA++, RA++	Sovereign	Recapping of key concepts	- Respond to questions asked - Mini activities of drawing structural formulas are done.
	PA++, RA−	Projected	Mathematical linking	
	PA++, RA++	Sovereign	Enforcing necessary skills for learning target content	
	PA+, RA+	Sovereign	Consolidating understanding	
2	PA++, RA++	Sovereign	Emphasise key points, deepen understanding	- Engaging with content through mini-writing activities.
3	PA++, RA++	Sovereign	Consolidating understanding through re-explaining target concepts.	- Learners work on a classwork activity.
	PA++, RA − −	Projected	Assessment	

From the table above, it is evident that the teacher was able to make shifts between sovereign codes (PA++, RA++, and PA+, RA+) and projected codes (PA++, RA− − /−) overtime in the lesson. This highlights that the teacher focused on ideas that are rooted within the technical sciences curriculum (PA++, PA+) while at the same time focusing on aims and purposes for deepening or enhancing understanding of organic chemistry (RA++, RA+). It can also be concluded that while the teacher managed to focus on ideas and purposes rooted within the technical sciences curriculum, more focus is however placed on ideas emanating directly from the topic of organic chemistry (PA++, RA++) as compared to targets within the general technical science curriculum (PA+, RA+). In addition, the shift to the projected codes (PA++, RA− − /−) suggests that the teacher maintained the focus on concepts from organic chemistry but through practices that did not directly enhance the learning of the concepts (RA−−, RA−). The detailed interpretation of the lesson below explicitly highlights the practices and dynamics that resulted in the shifts in autonomy codes mentioned above.

(ii) Individual lesson analysis for CT4

Episode 1

The lesson began with the teacher recapping key concepts from the previous lesson, thus establishing a foundation for linking previous concepts with new concepts. The previous concepts are central to the topic of organic chemistry, and they are explained to enhance learning of the topic. The lesson thus began with stronger positional autonomy (PA++) and relational autonomy (RA++). The recap included key concepts such as homologous series, and learners demonstrated their understanding through providing its definition. The teacher builds on this foundational knowledge by linking to the concept of functional groups and the general formula, which is described as an important feature in determining functional groups of organic compounds and an important concept linked to the topic of isomers.

Questions that helped the teacher to directly link previous concepts to the target content and purposes are posed, and learners provide written responses while the teacher moved around the classroom to assess their work. A general classroom interaction then emerged as learners' work is assessed, resulting in a shift from PA++, RA++ (sovereign codes) to PA++, RA− (projected), codes, in which relational autonomy is weakened as the teacher explained mathematical procedures of addition and multiplication to derive general formulas in organic chemistry; at this instance the molecule butane was used as an example. Following this, learners were tasked with the responsibility of identifying the homologous series and drawing the structural formula of butane. This approach then strengthened relational autonomy from RA- to RA++ since drawing of structural formulas forms part of operations introduced for the purposes of deepening target content. This marked a shift back to PA++ and RA++ (sovereign codes) as the focus shifted back to explanations relating to the target content and purposes that enhance learning of organic chemistry. The extract below highlights such transitions.

TEACHER: *To which homologous series does this one belong? There is carbon and hydrogen. Can you derive the general formula?*

Let's see there. ***Checking learners' written responses. Then reading the written response to the entire class***

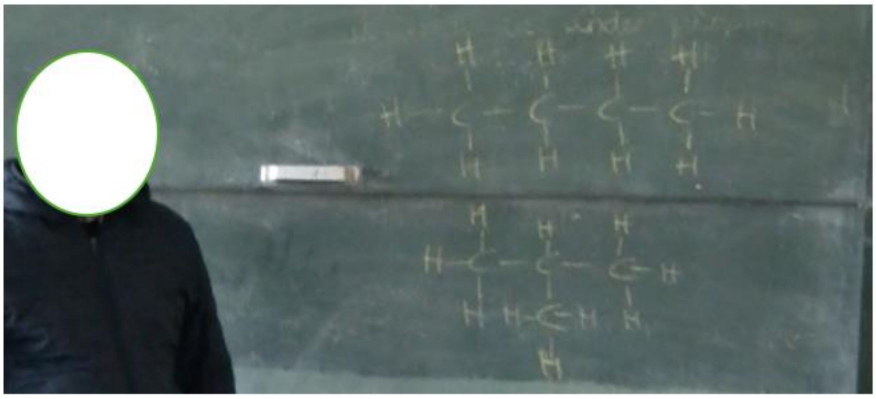
Cn, n here is 4, nhe (right)? There is n... H, right? 2n plus 2, so it's 4. 2 times 4 is 8. Plus 2 is what? It's 10? So, which homologous series does that one belongs to?

LEARNERS: *The alkanes.*

TEACHER: *Alkanes. Good! Just to see if you can still remember and understand this, I want you to draw the structure and structural formula of this molecule. Okay? In your books, draw the structural formula of* $C_4 H_{10}$.

Learners then take a moment to focus on drawing the structure.

Collectively, learners confirm the drawn structure of butane following the mini activity given by the teacher. Thereafter, learners are prompted to draw the structural formula of butane; it is assumed they can successfully identify and draw the structure based on previous knowledge. At this stage, PA and RA remain stronger (PA++, RA++) as the focus of the lesson is still on the target content and purposes. The isomer of butane is collectively identified and confirmed in the lesson; the teacher provides explanations that guided learners in correctly drawing the structural formula. In so doing, the focus of the lesson briefly shifts from concepts within organic chemistry to general science ideas in which the teacher points out that in its nature carbon forms four bonds (PA+, RA+). The explanations tie to the concept of covalent bonding of carbon, which is a general science idea necessary for learners to understand if they are to successfully draw structural formulas in organic chemistry. This slight weakening of positional and relational autonomy from PA++ and RA++ to PA+ and RA+ enabled the teacher to incorporate foundational knowledge into the lesson, thereby consolidating learning of the target content. Understanding is deepened through examining two structures drawn on the board (butane and its isomer, as seen in the diagram below)



Structure of butane and its isomer (2-methylpropane)

By comparison, the teacher explained that both structures share the same molecular formula, but the arrangement of atoms differs, thus reinforcing the concept of isomerism in organic chemistry. Consequently, a shift from PA+ and RA+ to PA++ and RA++ occurs, as both positional autonomy and relational autonomy are strengthened by returning to the target content of isomers, which was the main objective of this lesson.

Episode 2

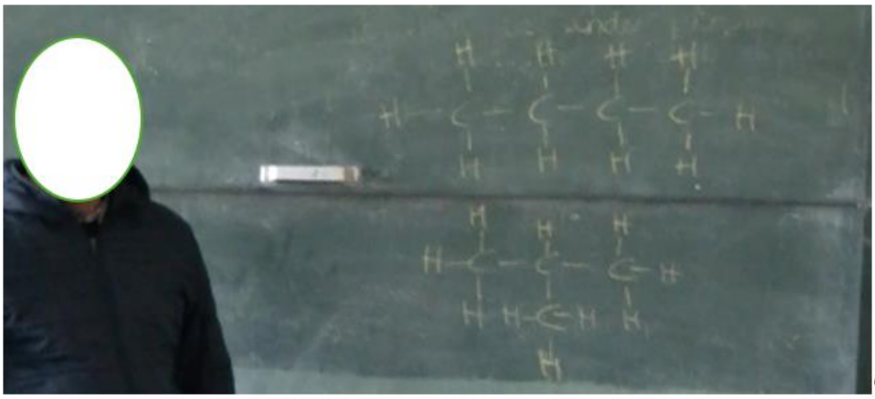
In episode 2, the focus remained on the sovereign codes (PA++, RA++) for the entire 10 minutes. The episode began with the teacher requesting learners to identify the name of the isomer of butane; this is an activity centred on the target content of organic chemistry. While learners were engaging with the task, the teacher is constantly moved around the classroom to check their responses. During the process, the teacher discovered that some learners have incorrectly named the isomer, which provided a chance for correction and re-emphasis of key organic chemistry concepts to enhance learners' understanding. See extract below.

TEACHER: *Alright, now what is the name here, a hydrocarbon with 3 carbons? Give the name there. The teacher checks the learners' written responses and says to the learner:*

You have a different name. 3 carbons? Remember we have meth, when it's two, it's eth then pro nhe (right)? Propane alright.

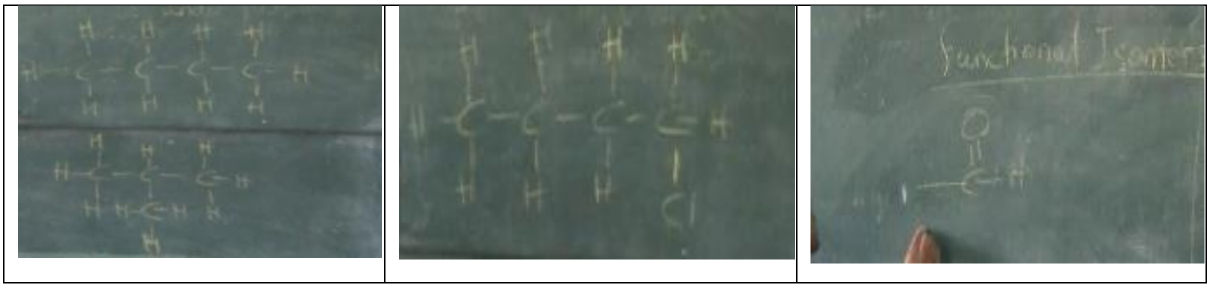
This interaction then led to an explanation directed to the entire class in which the teacher focused on explaining important aspects that learners should consider when it comes to naming isomers.

TEACHER: *Now remember this one here, so with the propane there was a hydrogen there.* [*Referring to the diagram of the isomer of butane once again].*



Now because this is here, you see this (referring to the branch of methyl on the second structure) is almost like a methane, except there's a hydrogen missing. Okay, so we call this group there; we call it an alkyl; it's actually methyl because it's one carbon. It's a methyl group there, okay.
Alright, and this methyl is on the second carbon; remember the number of the carbons is 1, 2, 3, alright, so if you name this one, you're going to say it is 2-methylpropane. okay?

This interaction emphasises key ideas on the topic of organic chemistry as the teacher focuses on key aspects and procedures that learners ought to understand for them to successfully name compounds. Indirectly, the teacher touched on the concept of IUPAC naming rules, which is important when it comes to naming compounds. As the lesson progressed, the focus remained on key organic chemistry concepts, with the teacher and learners collectively working together to identify different kinds of isomers. Learners actively engaged with the content by responding to questions, taking down notes, and drawing structural formulas for given compounds. Chain isomers, positional isomers, and functional group isomers are identified and discussed (as seen in the diagrams below). In the process, mistakes are rectified on the spot as the teacher re-explains concepts as necessary thus highlighting the advantages of contact sessions. While this episode is focused on ensuring mastery of key organic chemistry concepts and related skills, it is equally important to extend knowledge to other forms through incorporating knowledge from other domains or real-world examples. Doing so could enhance learners' understanding of the target content.



Examples of chain, positional and functional group isomers

Episode 3

The episode began with the teacher emphasising the importance of revising work and completing classwork activities. While this is not directly linked to target content and purposes, it highlights general educational expectations. As the lesson proceeded, learners were given a few minutes to give responses to a concluding classwork activity involving the concepts from the beginning of the lesson. The activity questions range from definitions of key concepts as functional groups and homologous series to identifying types of isomers, naming molecular structures, and drawing structural formulas for the identified isomers. The questions are consolidated at PA++ and RA++, where the teacher gave extended explanations or re-emphasised the target content.

Learners were required to critically engage with the content, and the target content and purposes were further reinforced as they drew structural formulas of organic compounds and offered responses that aligned with the target content. At one point, the teacher weakened relational autonomy to RA− − while positional autonomy remained stronger (PA++). The teacher shifted from target purposes (RA++) to non-target purposes (RA− −) by discussing assessment strategies. At this instant, the focus of the lesson was turned from purposes that enhance understanding of organic chemistry to non-target purposes that had nothing to do with the learning of organic chemistry. A transition from sovereign codes (PA++, RA++) to projected codes (PA++, RA− −) is thus noted. The lesson concluded on this note, where emphasis was placed on revealing ways in which learners can acquire more marks for their final grade 12 examination. The extract below highlights such an occurrence.

Learners are responding to the question of what an isomer is.

LEARNERS: *Same molecular formula but different arrangement of atoms.*

TEACHER: *Exactly, okay. Please guys, you must make sure that you get your marks. Your definitions are so important, so when you do revision, spend time doing revision on your definition, okay?*

TEACHER: *Which one is a hydrocarbon?*

LEARNERS: *It's A.*

TEACHER: *Why are you saying it's A?*

LEARNERS *It's A because there is no oxygen. Hydrocarbons are only between hydrogen and carbons.*

TEACHER: *Exactly. So, you see then when we look at these structures. This type of question you only get in question 2. When you open your question paper, you have multiple choices; you go to question 2, and you get this type of question. In this type of question, you must identify molecules; they ask questions about the functional groups, the definition of homologous series, and so on and so forth.*

Pulling the analysis together from episode 1 to 3, it is important to note that the shifts to the projected codes observed in this episode differ from those observed in episode 1. In episode 1, the teacher shifts to the projected codes (PA++, RA−) to focus on linking mathematical procedures to the understanding of organic chemistry concepts. In this episode, however, the teacher shifts to the projected codes (PA++, RA− −) for entirely non-target purposes where the focus is on assessment strategies rather than enhancing conceptual understanding. This distinction reveals that autonomy codes that shape integrative knowledge building can vary in their intention and outcomes.

(iii) Autonomy plane for CT4 lesson analysis

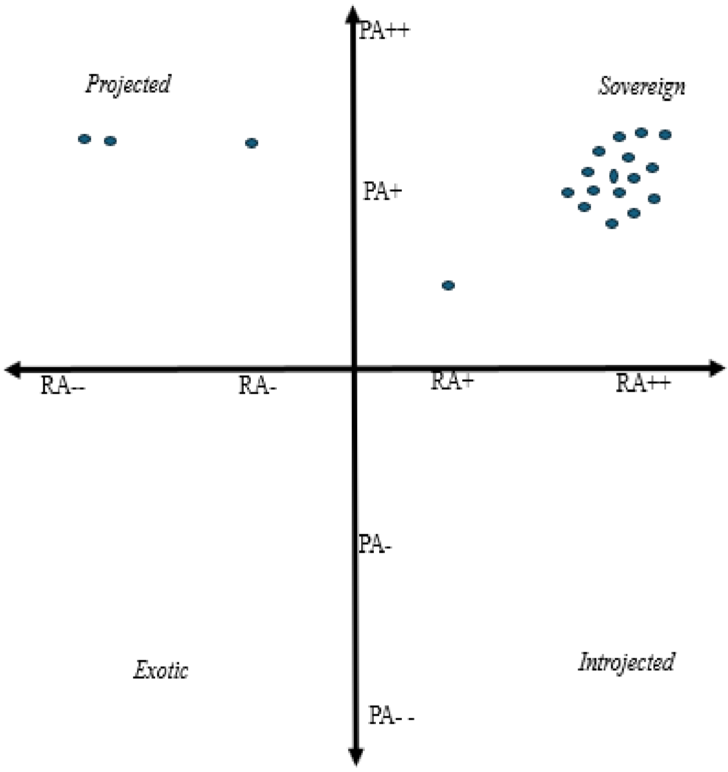


Figure 15: CT4 Autonomy plane

The autonomy plane above shows that CT4's lesson managed to shift between two codes, namely, sovereign and projected codes. The plane indicates that most of the teacher's practices are strongly grounded in the sovereign code, specifically PA++ and RA++. This reflects a dominant focus on organic chemistry concepts (PA++) associated with target-aligned purposes of enhancing conceptual understanding (RA++). Spending more time in this code also suggests strong alignment with the technical science curriculum along with pedagogical practices that enhance learning of knowledge within the curriculum. Along the lesson, limited ties with PA+ and RA+ are noted, with the focus on practices for scaffolding foundation knowledge to consolidate understanding of organic chemistry. While this code is still within the sovereign codes, the limited ties may present segmentation in terms of learners linking organic chemistry to other technical science concepts.

Noted from the plane, limited time is also spent on the projected codes, indicating insufficient tapping to the knowledge practices that focus on target content with emphasis on non-target purposes such as discussing examination strategies or using operations from other disciplines (e.g., mathematical linking in episode 1). The absence of shifts to the lower quadrants (exotic and introjected codes) suggests that knowledge that is not linked to any school subject (everyday knowledge). The teaching practices also remain grounded in technical sciences, with limited opportunities for drawing from other domains.

5.3.1.5. Summary of observations made from contact lessons

Across all the lessons, the sovereign code consistently dominates, suggesting that all the teachers managed to ground their lessons on the target content and purposes. The prominence of the sovereign code is justified given that the educational goal for any subject is to equip learners with knowledge and skills relevant for the subject. However, overly focusing on scientific disciplinary understanding has implications for teaching and learning where integrative knowledge building is concerned. According to Maton and Howard (2018), the goal of education is to integrate various forms of knowledge; this thus calls for teachers to opt for knowledge practices that foster integrative knowledge building (own emphasis). In the context of this study, this entails shifting between autonomy codes to venture into other domains to source knowledge.

The graph below provides a visual representation of the overall analysis of contact session lessons based on the autonomy shifts made by teachers in their lessons.

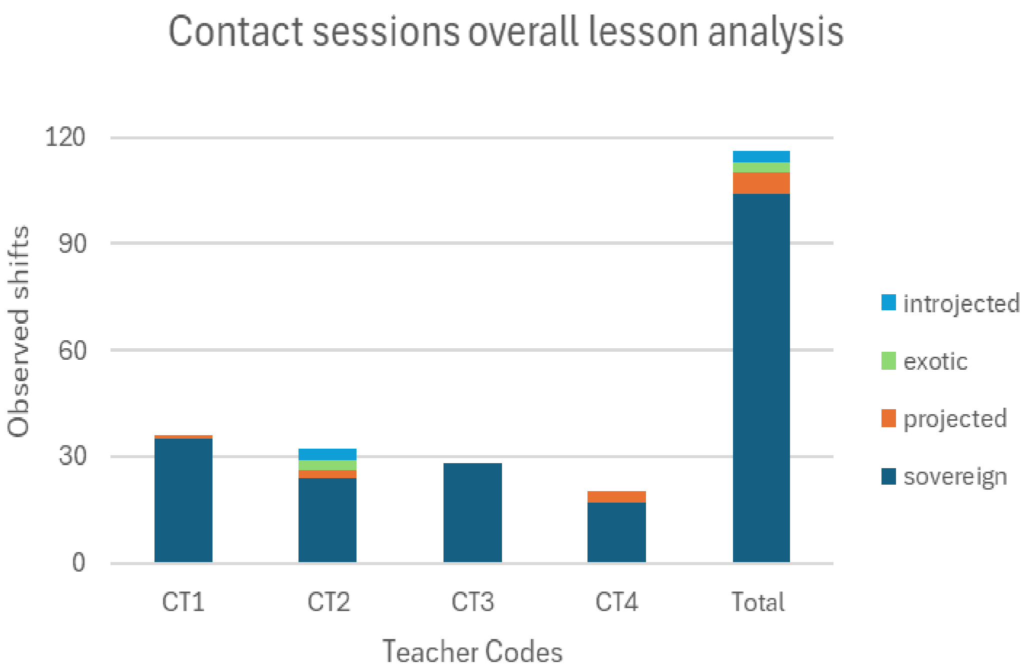


Figure 16: Graph showing overall analysis for contact sessions

Looking at all the lessons, CT2 emerges as the top teacher in offering opportunities for integrative knowledge building given that there is successful engagement with all four codes during instruction. CT2 lesson explored dynamic movements across codes as seen through the autonomy plane in figure 13. The teacher made shifts between target and non-target content or purposes countless times throughout the lesson. CT1 and CT4 are ranked on the same scale since both teachers managed to tap into two codes (sovereign and projected). Despite the shifts between the two codes, these lessons offer limited opportunities for integrative knowledge building since the knowledge is only limited to target content infused with practices that do not directly emanate from the science domain.

Due to narrowly focusing on knowledge practices aimed at enforcing understanding of scientific target concepts, the CT3 lesson remained confined to the sovereign codes throughout the lesson. Not drawing knowledge from other domains fosters a segmented approach to learning (Walton and Ruszynyak, 2019), which may hinder learners' ability to connect scientific knowledge with knowledge from other disciplines or real-world contexts, ultimately hindering integrative knowledge building. Despite the excellent shifts noted in the CT2 lesson, the cumulative total reflects the dominance of sovereign codes in these lessons. This demonstrates the need for CT1, CT3, and CT4 to opt for practices that align with the broader educational goal of creating learning opportunities that embrace the diversity of knowledge. As previously highlighted knowledge comes in various forms and embracing these varieties overcomes the issue of knowledge blindness (Maton & Howard, 2018).

5.3.2. Observations made from online sessions

5.3.2.1. Observations made from online lessons of OT1

The main purpose of this lesson was to develop learners conceptual understanding of the concept of organic chemistry. Through interviews and the lesson observations, the target content and purposes were confirmed. The lesson specifically focused on introducing learners to the concepts of homologous series particularly alkanes, alkenes and alkynes. The lesson was approximately 30 minutes and three episodes were identified.

(i) Translation device and episode analytical framework for OT1

The translation device in Table 24 highlights specific examples for both positional autonomy and relational autonomy as observed during the lesson then Table 25 shows autonomy codes in each episode.

Table 24: Positional and Relational autonomy translational device for online teacher 1 (OT1) lesson analysis

Strength	Codes (PA and RA)	1st Level Indicator	2nd Level indicator	Specific examples for OT1 lesson
Stronger	PA++, RA++	Target content and purpose	The teacher describes ideas from the topic of organic chemistry with the purposes of deepening understanding of the topic	So now we come to our main objective, the homologous series definitions. Right, so I asked you to take note of these definitions. Right, so what is a homologous series? So, this is a series of compounds that has the same general formula and the same functional group. Right, so what does this mean? When we talk about homologous series, we are saying it's a series of compounds that have the same general formula
	PA+, RA+		The teacher focuses on ideas that are not from organic chemistry but from the technical science curriculum in general. The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.	Right, so what I want you to take note of is that of course organic molecules have carbon like I said it's the main element. However, carbon dioxide, carbon monoxide, carbonate and cyanide, are not organic compounds.
	PA−, RA−	Non-Target content and purpose	Teachers uses ideas that are academic but are outside of the technical science curriculum and the purposes speak to other domains that are not unique to understanding organic chemistry	Right, but then so that's why I'm saying that we can use this word differently beyond chemistry. Right, so this includes like some of you have thought of organic food, organic growth and organic degeneration. But yes, like I said I know it's a bit confusing when we are going to look at this word from the chemistry point of view. Right, I said science has its own language.
Weaker	PA− −, RA − −		The teacher explains ideas that are not linked to any school subjects; thus, the purposes do not enhance learning of organic chemistry/any school subjects	So, most of you might think of vegetables and all that I know. Right, so just for the two minutes that I gave you, some of you thought organic. When you think of the word organic, what comes into your mind is like fruit and veg. 

Table 25: Codes observed in relation to the lesson episodes

Episode	Codes enacted	Code Name	For what purposes?	Role of the teacher in each episode.	Assumed role of the learners in each episode
1	PA− −, RA − − (1)	Exotic	To link general understanding to organic chemistry	- Teacher outlines target concepts. - Outlines key objectives. - Challenges learners to briefly think about what organic chemistry is before commencing with the lesson. - Elicit prior knowledge	- Pause the video to think about the concept of organic chemistry.
	PA− −, RA − − (2)	Exotic	Show distinction between general language and chemistry language		
	PA− −, RA − − (3)	Exotic	To expand general understanding of the term		
	PA−, RA −	Exotic	Link the concept to other academic knowledge domains.		
	PA+, RA+	Sovereign	Laying a foundation for the target concept		
	PA++, RA++	Sovereign	Deepen understanding		
	PA+, RA+	Sovereign	Consolidate understanding		
2	PA++, RA++	Sovereign	Deepen understanding	- Detailed explanations. - Posing questions (which the teacher later responds to)	N/A
	PA− − , RA++	Introjected	Linking common understanding to the target concept		
	PA++, RA ++	Sovereign	Deepen understanding		
	PA+, RA+	Sovereign	Consolidate understanding		
	PA++, RA++	Sovereign	Deepen understanding		
	PA− −,RA++	Introjected	Linking common understanding to the target concept		
	PA++, RA++	Sovereign	Deepen understanding		

3	PA++, RA++	Sovereign	Deepen understanding	- Learners reminded of the objectives. - Facilitating class activities	N/A
	PA++, RA−	Projected	Linking understanding using procedures borrowed from mathematics		
	PA++, RA++	Sovereign	Deepen understanding		
	PA++, RA−	Projected	Linking understanding using procedures borrowed from mathematics		
	PA++, RA++	Sovereign	Deepen understanding		
	PA++, RA−	Projected	Linking understanding using procedures borrowed from mathematics		
	PA+, RA+	Sovereign	Consolidate understanding		
	PA++, RA++	Sovereign	Deepen understanding		

The translation device above indicates successful integration of target and non-target content and purposes in this lesson. This is indicated by the ability of the teacher to tap into all the positional autonomy and relational autonomy codes over time in the lesson. There is clear visibility of examples pertaining to PA++ all the way to PA−− and likewise examples relating to RA++ all the way to RA−− are observed. This further suggests the ability of the teacher to successfully focus on ideas that are emanating from the topic of organic chemistry (PA++), general science ideas (PA−), ideas from other domains (PA-) and non-academic ideas (PA−−) In relation to the purposes or aims of the lesson, the teacher successfully focuses on purposes for deepening learning of organic chemistry (RA++), using other science concepts to learn about organic chemistry (RA+), using other knowledge sources or domains (RA−) and purposes that do not directly enhance learning of organic chemistry (RA−−).

To clearly visualise the shifts in autonomy codes enacted by OT1, Table 25 above presents the codes in relation to the identified episodes. The conditions for the enactment of these codes, as well as the roles of the teacher and learners, are highlighted. Unlike in contact sessions, the role of the teacher in online instruction is clearly defined, as teachers often direct the lessons in such contexts. From the episode analytical framework, it is noted that the teacher managed to tap into all the four autonomy codes: exotic, sovereign, introjected and projected over time in the lesson. A notable pattern is the repetition of the exotic code in Episode 1 for different purposes. The different purposes for the use of these exotic codes explains the emerging labels of PA−−, RA −− (1), PA−−, RA −− (2) and PA−−, RA −− (3). The purpose for the other codes (sovereign, introjected and projected) are consisted with the ones observed in some contact lessons. The role of learners can be said to be as assumed roles since the teacher cannot confirm if learners are indeed engaging with the content and specific instruction given during the lesson. Even though the role of the teacher is explicit, it cannot be directly translated into aspects that influence how the learners process the content knowledge in asynchronous instruction. The above point will be further explored in the lesson analysis based on the episodes' analytical framework.

(ii) Individual lesson analysis of online session for OT1

Episode 1

The lesson began with the teacher outlining the target content and purposes thus setting a clear direction of how the overall lesson will proceed. As the lesson begins, the teacher states that the focus of the lesson will be on three functional groups: alkanes, alkenes, and alkynes. From the beginning, emphasis is placed on the importance of learners having to understand the key terminologies related to organic chemistry such as homologous series and functional groups. See extract below:

TEACHER: *So, for today we are starting with our new topic on organic chemistry. So, what we will do for today is just the introduction to organic chemistry. With this lesson of ours we must first know the lesson objective. So, since we are doing introduction to organic chemistry, what I want us to focus on is just the three functional groups. So, we are going to look into the homologous series definitions mainly of alkane, alkene and alkyne. Please take note of this. So, there are many homologous series and many functional groups but for today we are just only going to look into the three alkane, alkene alkyne and take note of the wording that I am using. I am saying homologous series, I am saying functional groups. So just take note of this and we will focus more on this during the lesson, and you will take note of all those definitions. We will go on and discuss organic chemistry or discuss all this, so far, the terminologies that I've just mentioned homologous series, functional groups and all that. We first need to understand what organic chemistry is.*

The above extract clearly reveals the intention of the teacher to foreground the objectives as well as the key concepts, indicating that these concepts will be central in the overall lesson. This clarity is essential in an asynchronous format where learners do not have immediate access to the teacher for clarification. In addition, the clear direction that the teacher is giving provides an entry point for learners to be able to focus on the targets despite the non-target content and purposes that unravel in the overall lesson. Following the outlining of objectives the teacher started off the lesson on weaker positional autonomy (PA − −) and relational autonomy (RA− −). This entails that the focus is on non-target content and purposes whereby the teacher explains ideas that are not linked to any school subject (everyday knowledge) for the purposes that do not enhance the direct learning of organic chemistry. The teacher then directed learners to pause the video for two minutes to think about what organic chemistry is. By doing so, the teacher activates learners prior understanding of the concept thus establishing an entry point into learners assumed thoughts before proceeding with the lesson.

Even though there is no confirmation of whether learners paused the video or not, the directive from the teacher was aimed at allowing learner to actively participate within the asynchronous learning contexts. Following the directive for learners to pause the video, the teacher then gave an assumed reflection on behalf of the learners as the teacher went on to say: "*So most of you might think of vegetables and all that I know. Right, so just for the two minutes that I gave you when you think of the word organic, what comes into your mind is probably organic fruits and vegetables*". This statement highlights general understanding that learners may bring into the learning environment thus it is denoted as PA− − and RA− − (1).

As the lesson progressed the teacher further moved away from the targets, shifting focus to the distinction between general language and chemistry specific language. This is denoted as PA− −), RA− −(2) since the focus is still on the non-target content and purposes. However, the focus has completely transitioned from eliciting prior knowledge to an understanding of science language in relation to general language. This shift is necessary to help learners develop the required linguistic foundation for engaging with organic chemistry concepts later in the lesson. There is no doubt that the teacher acknowledges the learners' prior understandings by emphasising that while their prior knowledge may be correct it is not the central focus of the current lesson. The extract below highlights such an instance.

TEACHER: *But then in chemistry or in science we need to know that there is language for science. So, there is science language and there is English or general language. Right! So, the word organic may be used differently in our everyday life as compared to how we use the word organic in chemistry.*

Following this statement, the teacher shifted even further from the target content, as the explanations regarding the language distinction are paired with the teacher noting that some learners may associate the term "organic" with a garden or backyard. This explanation is denoted by PA− −,RA− − (3) since the purposes for the enactment are completely different from PA− −, RA− − (1) and PA− −, RA− −(2). In PA− −, RA− −(3) the teacher states: "*Right, so like I said you will see in the slides that I said the word organic is now used in several different contexts beyond chemistry. So, we can use it in many ways. Like some of you might have thought that when you think of the word organic, you're thinking fruit and vegetables, you may be thinking that I am talking of my garden or my backyard.*"

Based on the target content and purposes outlined for the lesson, it is apparent that the teacher needs to refocus explanations back to organic chemistry concepts. Without this shift, learning at this point would have limited relevance to the understanding of the target concepts. The teacher takes a step towards strengthening the positional autonomy and relational autonomy by shifting to PA− and RA− where the focus is on ideas that are academic but outside of the technical sciences curriculum. These ideas are established to create links between organic chemistry and knowledge from other disciplines. While this knowledge is still somewhat distant from the key concepts, they signal a return to the target content and purposes.

The teacher then proceeded to mention words that are associated with the term 'organic' beyond organic chemistry. Some of these terms such as organic growth originate from business studies and explain the growth a company achieves by increasing output and enhancing sales internally. While other terms such as organic degeneration stem from the biology or life sciences domain and refer to an organic mental disorder. Terms like organic food is linked to physical sciences or chemistry and refer to foods that are produced through farming practices that only use natural substances. To further confirm that the purposes for the mentioning of these terms have little to do with the learning of organic chemistry, the teacher explained that the terms are introduced to allow learners to understand the distinction in the uses of the term 'organic'. The teacher further mentioned that such an understanding will allow learners to make room for the learning of the key concepts central to organic chemistry. Consequently, the teacher unintentionally addresses potential misunderstandings or misconceptions that may result from the multiple meanings associated with the term 'organic'. This clarification is reinforced as the teacher does not simply introduce these terms but elaborates that, in the context of this lesson, the term 'organic' will specifically be examined from the perspective of a technical sciences, rather than from the other disciplines mentioned earlier. Meaning is not only left at this point, but the teacher further strengthens positional autonomy and relational autonomy by shifting to PA+, RA+. At this point the focus is on general science ideas (PA+) introduced for the purposes of learning about organic chemistry (RA+). The extract below highlights such a shift.

***TEACHER**: So, in chemistry, in science education, not in everyday life but in science class in our grade 12 science class when we talk about organic chemistry we are referring to the chemistry of carbon compounds. So, we are looking mostly at carbon compounds. You know compounds, when carbon is joined to other elements? So, we are looking at that!*

The chemistry of carbon which is the main element there. The chemistry of carbon compounds in living and non-living systems. Right, so what I want you to take note of is that of course organic molecules have carbon like I said it's the main element. However, carbon dioxide, carbon monoxide, carbonate and cyanide, are not organic compounds. Right, so we do not consider carbon dioxide or carbon monoxide or carbonate as organic compounds even though they have carbon in them. Right, because they are what we refer to as inorganic. So, inorganic usually have this backbone of linked carbon atoms that other atoms are attached to. Right, so just take note of that.

The above extract highlights explanations relating to general science knowledge. The teacher touched on the chemistry of carbon which is the main element in organic chemistry. At this point the teacher is clearly moving a bit closer to the targets as there is a mention of the types of inorganic compounds. This allows for an entry point to the concept of organic chemistry which is the target for this lesson. The teacher thus shifted from PA+ and RA+ to PA++ and RA++ as the focus turns to an explanation of what makes up organic compounds. See extract below.

TEACHER: *In organic chemistry, we focus on compounds that contain carbon. These are called organic compounds because carbon is the key element that defines them. So, what we are going to focus on in organic chemistry include compounds that has carbon, and contain atoms such as hydrogen, oxygen and halogens.*

Immediately following the mention of what the focus of this lesson is about, the teacher slightly weakened PA and RA from PA++ and RA++ back to PA+ and RA+ as the focus was on consolidating understanding of aspects mentioned in the extract. Here, the teacher explained the nature of carbon, halogens, hydrogen and oxygen, additionally the teacher explained the chemical bonding of these atoms. This is general science knowledge from the technical science curriculum but not entirely ideas of the target concept. The diagram below anchors the explanations given by the teacher.

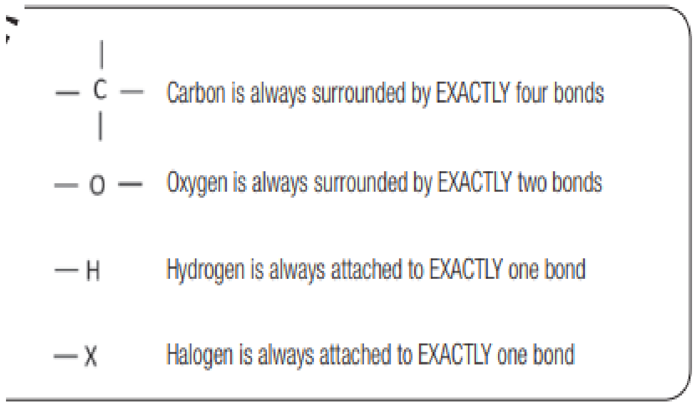


Diagram showing explanation of atoms mostly involved in organic compounds

This episode thus concluded on a slightly stronger positional and relational autonomy (PA+ and RA+). The teacher highlighted that for learners to understand chemical bonding of these atoms, they need to revisit the concept of valence electrons from previous grades, particularly grade 10. Learners are encouraged to draw on their prior knowledge hence this shift is denoted as PA+, RA+ since the focus is on science ideas emanating from the general technical sciences curriculum.

Episode 2

Episode two began with the teacher explaining key definitions of homologous series and functional groups. Thus, the teacher explained ideas from the topic of organic chemistry as prescribed through the technical sciences curriculum (PA++) and these ideas are explained for the purposes of deepening understanding of organic chemistry (RA++). From the previous episode there is an explicit strengthening of PA and RA from PA+ and RA+ to PA++ and RA++ in this episode. The extract below highlights such an instance.

TEACHER: *So now we come to our main objective, the homologous series definitions. Right, so I asked you to take note of these definitions. Right, so what is a homologous series? So, this is a series of compounds that has the same general formula and the same functional group. Right, so what does this mean? When we talk about homologous series, we are saying it's a series of compounds that have the same general formula. So, a general formula is like an expression. These expressions will tell you how many carbon atoms are here; how many hydrogens are here. Right, so this is that expression. You will see in the table that follows what is this general formula that we're talking about. (referring to the diagram below)*

Classification of organic molecules according to homologous series

Homologous series		General formula	Functional Group	Suffix	Example name	Structural formula	Condensed structural formula	Molecular formula
Hydrocarbons	Alkanes	C_nH_{2n+2}	$-\overset{\vert}{\underset{\vert}{C}}-\overset{\vert}{\underset{\vert}{C}}-$	-ane	propane		$CH_3CH_2CH_3$	C_3H_8
	Alkenes	C_nH_{2n}	$>C=C<$	-ene	propene		$CH_2{=}CHCH_3$	C_3H_6
	Alkynes	C_nH_{2n-2}	$-C\equiv C-$	-yne	propyne		$CH{\equiv}CCH_3$	C_3H_4
Haloalkanes/ alkyl halides		$C_nH_{2n+1}X$ (X = F, Cℓ, Br, I)	$-\overset{\vert}{\underset{\vert}{C}}-X$	-ane	2-bromopropane		$CH_3CHBrCH_3$	C_3H_7Br
Alcohols		$C_nH_{2n+1}OH$	$-\overset{\vert}{\underset{\vert}{C}}-O-H$	-ol	propan-2-ol		$CH_3CHOHCH_3$	C_3H_7OH
Aldehydes		$C_nH_{2n}O$ n =1, 2, ...		-al	propanal		CH_3CH_2CHO	C_3H_6O
Ketones		$C_nH_{2n}O$ n = 3, 4, ...		-one	propanone		CH_3COCH_3	C_3H_6O
Carboxylic acids		$C_nH_{2n}O_2$ n = 1, 2, ...		-oic acid	propanoic acid		CH_3CH_2COOH	$C_3H_6O_2$

Diagram showing classification of molecules according to homologous series

To explain the relationship between a homologous series and a functional group effectively, the teacher greatly weakened positional autonomy from PA++ to PA− −while relational autonomy remained stronger at RA++. The weakening of PA established a shift from the sovereign codes (PA++, RA++) to the introjected codes (PA− −, RA++). This shift was necessary to allow learners to understand the complex concept of functional groups which often present problems for learners to understand when learning about organic chemistry. By weakening PA, the teacher was able to integrate everyday examples making learning more relatable. This was achieved through the use of an analogy comparing homologous series to a general family, as demonstrated in the extract below.

TEACHER: *So, when we talk about homologous series, we are saying these compounds, they are under the same family. If I can use this analogy, they are under the same family. The difference is the number of carbon atoms and the number of hydrogen atoms. It's like in a family you have people with different age groups, but they are under the same family. So, a homologous series is that series of compounds that have the same general formula and the same functional group.*

The same as in your family you have the same surname. You stay in the same house but all of you are different with regards to your age. So, the same here with homologous series, the difference only applies to the number of carbon atoms and hydrogen atoms. However, they are still in the same functional group. Are we okay with that? Yes, so take that as homologous series.

The extract above is insightful for two reasons. Firstly, the teacher does not just choose any analogy but uses a simple analogy that most learners can relate with. Secondly, the teacher ensures that there is a clear relationship between the analogy and the target content. Doing so enhances the overall understanding of the concept of homologous series and functional groups. Understanding is not only left at PA− −, the teacher strengthened PA back to PA++, thus successfully establishing a shift from the introjected codes back to the sovereign codes (PA++, RA++). At this instance, the focus shifted to the target concepts of saturated and unsaturated hydrocarbons which were established as integral concepts in this lesson. This shift is again followed by the weakening of both PA and RA to PA+ and RA+ where the teacher focused on general science knowledge introduced for the purposes of enhancing understanding. At this point, the teacher revisited the concept of chemical bonding in carbon to explain how saturated compounds are formed. To do this, the teacher explicitly scaffolded understanding by drawing a diagram using PowerPoint drawing tools (as seen below) so that learners can clearly follow the explanations.

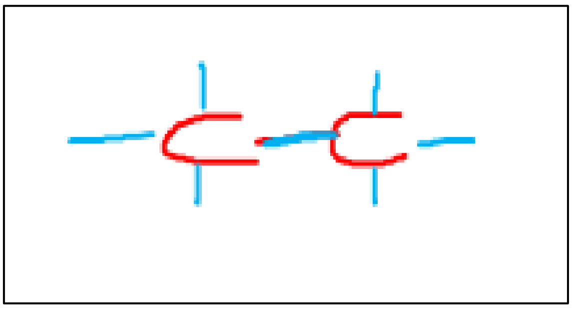


Diagram drawn using PowerPoint tools showing a saturated compound

Understanding is not confined to general scientific knowledge (PA+, RA+); instead, the teacher strengthened PA and RA by shifting back to PA++ and RA++. At this point, there are explanations that relate saturated compounds with unsaturated compounds using organic chemistry terms. To consolidate this understanding, the teacher presented a diagram that highlights the key differences between the two types of compounds, as shown below.

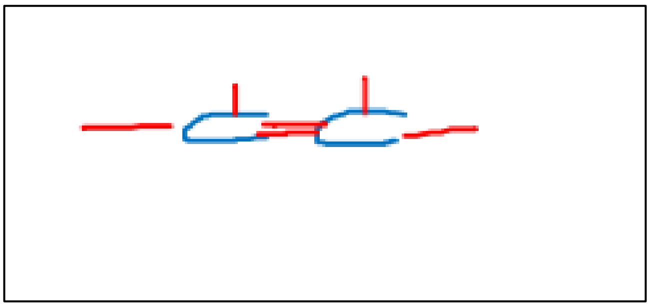


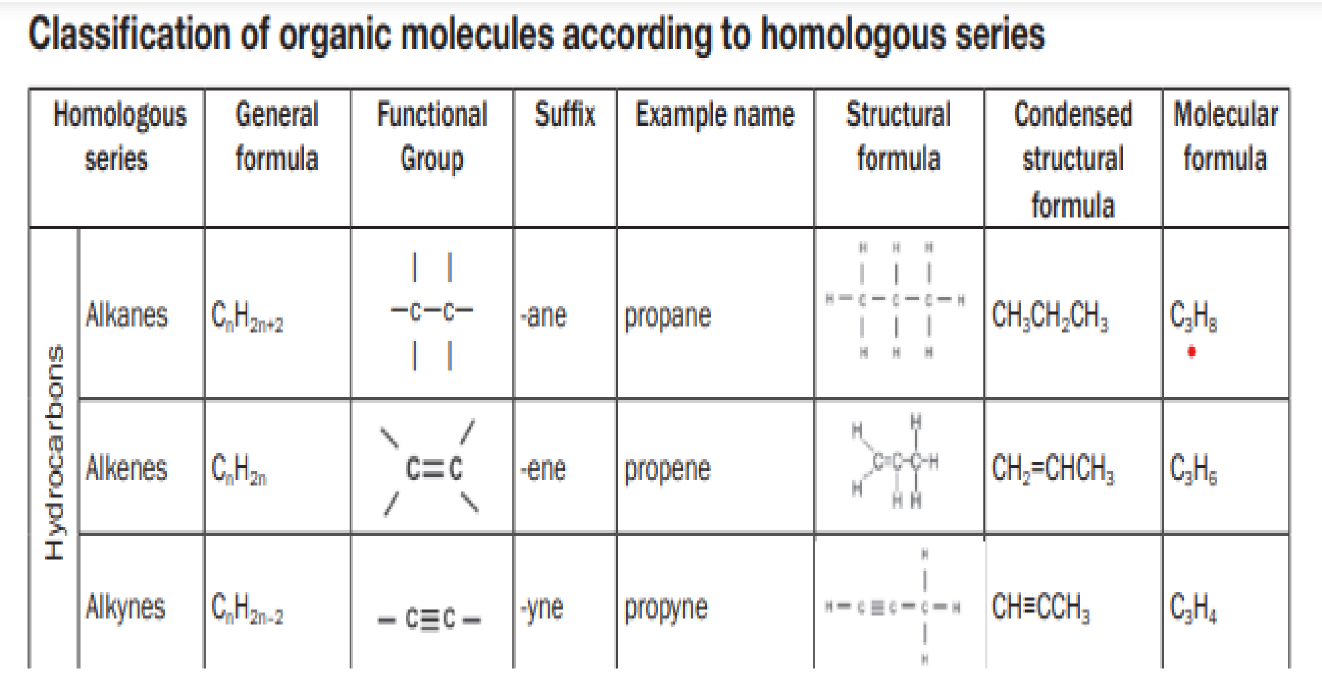
Diagram drawn using PowerPoint tools showing unsaturated compound

From the instance above, the teacher signalled a content progression from saturated and unsaturated compounds to the concept of functional groups which appears to be the key concept in this lesson. It appears the teacher intended to pick up from where she left off from the beginning of the episode. A brief shift from PA++ and RA++ to PA− − and RA++ is noted as the teacher revisited the analogy of a family that was introduced at the beginning of the episode. To link the analogy once again to the target content the teacher weakened PA to PA− − while RA remains at RA++. A shift from the sovereign code to the introjected codes is again noted in this episode. It is noteworthy that understanding is not left at PA- - as the teacher concluded the episode by shifting back to PA++ thus establishing once again a shift from introjected codes to the sovereign codes. The series of strengthening and weakening of PA in this episode enable learners to connect target and non-target concepts, fostering a broader understanding of key concepts.

The episode ends with the teacher explaining that functional groups determine the physical and chemical properties of organic compounds. Furthermore, learners are provided with a table that shows different functional groups and homologous series. The main objective of the lesson is reinforced as the teacher mentioned that the focus is on three homologous series: alkanes, alkenes and alkynes. This episode is characterised by detailed explanations and repeated emphasis of key concepts which may be considered important especially in asynchronous learning contexts. Such a practice provides learners with clarity and reinforcement helping them understand the content without the immediate support from the teacher.

Episode 3

The episode began with the teacher reiterating the objectives of the lesson. As the lesson progressed, the teacher consistently reminded learners of these objectives, which is particularly beneficial in asynchronous learning contexts. Doing so helps learners stay focused and navigate the content independently, thus ensuring they remain aligned with the intended outcomes even without real-time guidance. The episode further proceeded with the teacher introducing a table that focuses on the homologous series which she outlined as the key focus in this lesson. This table describes ideas from the topic of organic chemistry thus the episode begins on a stronger positional autonomy and relational autonomy (PA++, RA++). See figure below.



Classification of organic molecules according to homologous series

	Homologous series	General formula	Functional Group	Suffix	Example name	Structural formula	Condensed structural formula	Molecular formula
Hydrocarbons	Alkanes	C_nH_{2n+2}	$-C-C-$	-ane	propane		$CH_3CH_2CH_3$	C_3H_8
	Alkenes	C_nH_{2n}	$C=C$	-ene	propene		$CH_2=CHCH_3$	C_3H_6
	Alkynes	C_nH_{2n-2}	$-C\equiv C-$	-yne	propyne		$CH\equiv CCH_3$	C_3H_4

Figure 17: Classifying homologous series of alkanes, alkenes and alkynes

From the table above, the teacher revisited concepts introduced in previous episodes, such as the general formula. The teacher explicitly guided learners to focus on the general formula equations and emphasised this point by stating that, "*This is the general formula that I was mentioning earlier.*" The focus in this episode appears to be equipping learners with knowledge and skills that help them understand the derivates of general formulas for alkane, alkene and alkynes. Doing so necessitated a shift from PA++ and RA++ (sovereign codes) to PA++ and RA− (projected codes) where the relational autonomy is weakened as the teacher borrowed procedures from mathematics to explain the conceptualisation of the general formula of alkanes as highlighted in the extract below.

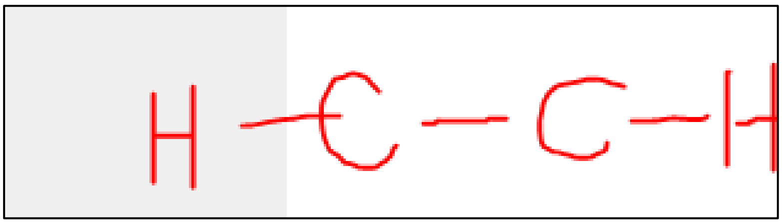
TEACHER: *For instance, if we will have three carbon atoms, so this n is just like a variable, like in mathematics. So, this n is the same as a variable, meaning it can be any number. So,*

when we say we have three carbon atoms, so it's going to be C_3, right? And then for hydrogen atoms, you will then have to multiply that n by 2 and you add 2. So that's the general formula for alkanes. You have C_nH_{2n+2}. That's how you get your general formula for alkanes, right? So, let's do this example that's given here. So, we're going have three carbon atoms, meaning our hydrogen atoms will be what? 3 times 2 or 2 times 3, 6 plus the other 2, 10. Are we okay? So now I want us to look at this structural formula.
For instance, we have three carbon atoms, 1, 2 and 3. You can see, let me use the red colour (highlighting using PowerPoint tools). So, three carbon atoms, right? And then we said how many H's should be there? So, this is what you should just know from the general formula. So, the H's that we will have, if we have three carbon atoms, then we will just say 2 times 3 plus 2 that is 8. So, meaning, and remember how you remember the bonds. So, we have, we know that carbon atom is supposed to be bonded or surrounded by four bonds.

From the extract above, the teacher drew connections between aspects of the general formula and mathematical variables, clearly indicating to learners that despite the focus being on organic chemistry, there is a relationship between the general formula equations and mathematical procedures. Doing so reinforces the idea that concepts being taught in this lesson are not isolated to organic chemistry or technical sciences only but draw on a range of skills and knowledge from other disciplines. Following this, RA is strengthened from RA- to RA++ where the teacher linked the mathematical procedures with the target purposes to enhance overall learning of organic chemistry. A shift from PA++ and RA− to PA++ and RA++ is noted as the teacher repacked understanding by explaining how the general formula derived above relates to alkanes in terms of the structural composition.

As the lesson proceeded, there is a series of weakening and strengthening of RA from RA++ to RA- and vice versa. This entails a shift between the sovereign code (PA++ and RA++) and projected codes (PA++ and RA−). Since the teacher mentioned that the target is on the three homologous series, the teacher then further proceeded with explaining the derivation of the general formula for alkenes and alkynes using mathematical procedures hence RA−. While doing so, the teacher ensured that enough explanations that link the mathematics procedures to the target content and purposes are emphasised. A different shift is however noted in this episode when the teacher shifted from PA++ and RA− to PA+ and RA+. This shift is observed when the teacher explained why alkynes contain two hydrogen atoms in their structural formula, as highlighted in the extract below.

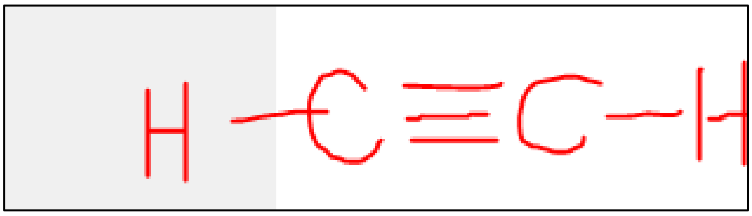
__TEACHER:__ So, we can move on to this last one, alkyne, Y-N-E. Take note of the suffix, right? So, for alkyne, the function of the general formula is C_nH_{2n-2}. So, let's take for instance, again, we have two carbons. So, our n is 2, and if our n is 2 then it means hydrogen atoms will have two times which is four minus two. Four minus two is two, meaning I am going to have only two hydrogen atoms. So let me put the hydrogen atoms *here (drawing the H on the C atoms as shown on the diagram below). Just to show you, so we have two hydrogen atoms. Right!*



But how many bonds are supposed to surround our carbon atom? Between the carbon atom we know there is one bond, so how many boards are supposed to carbon atom? We know its' four. So, what do we do? We know that hydrogen atoms cannot be bonded to more than one atom, so meaning we must put the bonds in between the carbons.

As the teacher asked, "*But how many boards are supposed to surround our carbon atom?*", the explanation given marked a shift to PA+ and RA+ since the teacher revisited the concept of chemical bonding of carbon and indirectly connects to the concept of valence electrons which was introduced as prior knowledge in Episode 1. However, understanding is not left at general science knowledge (PA+, RA+), the teacher concluded the lesson by responding to the rhetorical question posed for learners using organic chemistry ideas. This marks a shift to PA++ and RA++ as highlighted in the extract below.

TEACHER: *So, it's one, two, three and four (referring to bonds as shown below)*



So how many bonds do we have for the first carbon, one, two, three, four. Four bonds! So the first carbon is okay. How many bonds for the second carbon? One, two, three, four…so the second carbon is also fine. They are both surrounded by four bonds. So now what you have to *take note of is that if we have three bonds like this one (referring to the picture above) in between the carbon atoms then we are talking about alkynes, YNE. Alkynes because they have more than one bond, they are unsaturated.*

The above extract highlights how the teacher deepened overall understanding by consolidating understanding of unsaturated compounds and general structural formula of alkynes in this lesson. By doing so, OT1 ensured that the learning moved beyond a basic understanding of general science, allowing learners to engage with and comprehend the key concepts the lesson aimed to convey. Overall, in episode 3 more rhetorical questions were noted as the teacher shifted between the autonomy codes. For example, the teacher would ask "*Are we okay with that?", "So what do we do*"? (asked when drawing structural formulas), "*But how many bonds are supposed to surround our carbon atom*?" and "*How many bonds for the second carbon*?".

Even though learners cannot directly respond to the questions, these questions serve important functions as they facilitated the shifts between autonomy codes. Considering that this is an asynchronous lesson, the teacher invited learners to mentally participate in the lesson, fostering a sense of involvement. In additional the rhetorical questions contribute to a conversational tone thus making the lesson feel more interactive and less like a one-sided session. This is particularly important in asynchronous learning, where the lack of immediate feedback can make the learning experience feel isolated.

(iii) Autonomy plane for OT1 lesson analysis

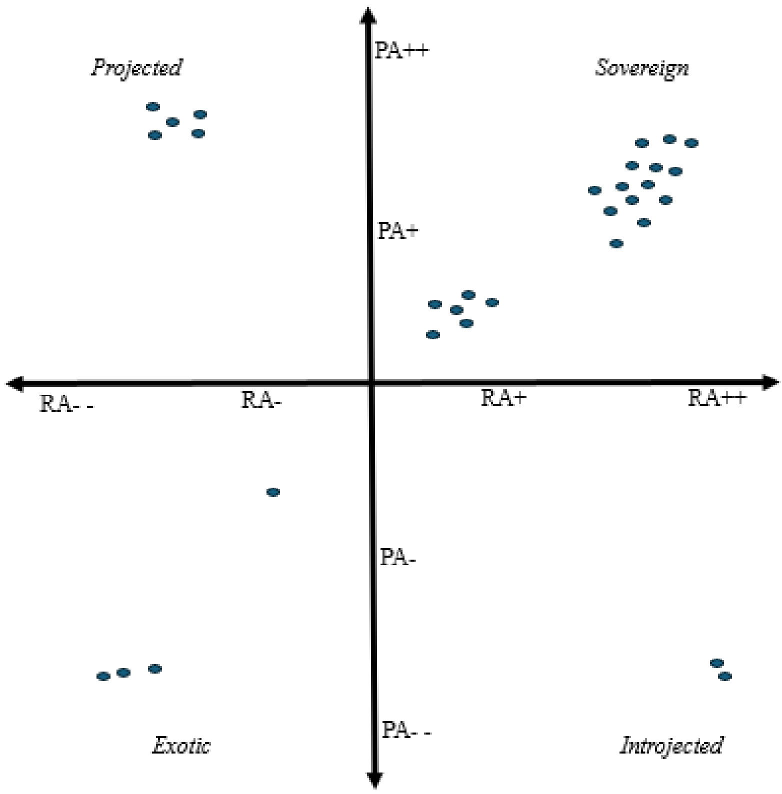


Figure 18: OT1 Autonomy plane

Overtime in the lesson, OT1 manages to shift to all four codes namely: exotic, sovereign, introjected, projected. Within the exotic codes the teacher taps on practices that do not enhance the learning of organic chemistry (non-targets). In contract, within the sovereign codes, the teacher is able to focus on ideas emanating from organic chemistry and carry out purposes and aims that deepen understanding of the topic (targets). In the introjected codes, the teacher manages to tap into non-target ideas using operations or purposes of learning science (non-target content coupled with target purposes). Finally, within the projected codes, the teacher focuses on knowledge practices that target the teaching and learning of organic chemistry concepts (target concepts) but use operations that do not enhance the learning of those concepts (non-target purposes) e.g. mathematics operations.

Although the teacher manages to shift to all the codes, it is explicit from the plane that the dominant quadrant is the sovereign codes (PA++ and RA++); (PA+ and RA+). Spending a significant amount of time in the sovereign codes is necessary as it ensures that learners grasp the scientific concepts fully, which is the goal of this lesson. However, overstaying within this code can hinder integrative knowledge building. In this lesson, the teacher effectively shifts to other codes, clearly presenting interdisciplinary learning opportunities for learners. This ensures that learners see how the target concepts relate to other sources of knowledge, thus allowing them to make connections between forms of knowledge. While shifting to the other codes is necessary, the teacher ensures the stay is brief. This guarantees that the shifts to other codes do not detract from the primary goal of the lesson, which is to deepen understanding of organic chemistry. These shifts only serve the purposes of consolidating, linking and creating an entry point for learning the key concepts.

5.3.2.2. Observations made from online lessons of OT2

Similar to OT1, the teacher confirmed this lesson was an introductory to organic chemistry. The focus in this lesson was however on IUPAC naming of organic compounds or molecules. In addition, during the interviews the teacher mentioned that concepts such as homologous series and structural formula were incorporated to complement the central concept of IUPAC naming.

(i) Translation device and episode analytical framework for OT2

The lesson was approximately 30 minutes, and three episodes were identified and analysed. Table 26 and 27 provides specific examples of positional and relational autonomy and autonomy codes enacted per episode respectively.

Table 26: Positional and Relational autonomy translational device for online teacher 2 (OT2) lesson analysis.

Strength	**Codes (PA and RA)**	**1st Level Indicator**	**2nd Level indicator**	**Specific examples for OT2 lesson**
Stronger	PA++, RA++	Target content and purpose	The teacher describes ideas from the topic of organic chemistry with the purposes of deepening understanding of the topic	When a molecule, or when a compound, an organic compound, has only one carbon, it takes a prefix myth. All right? And then, if it only has two carbons, it takes the prefix eth.
	PA+, RA+		The teacher focuses on ideas that are not from organic chemistry but from the technical science curriculum in general. The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.	We're going to be looking at organic chemistry but to be more specific we're going to be studying the chemistry of the carbon atom. So, let's go to our periodic table and look for this carbon atom.
	PA−, RA−	Non-Target content and purpose	Teachers uses ideas that are academic but are outside of the technical science curriculum and the purposes speak to other domains that are not unique to understanding organic chemistry	So human beings are made up of carbon. In fact, 18% of the human body is made up of carbon. So, the sugars, the glucose, protein, and all of those, they're made up of carbon.
Weaker	PA− −-, RA − −		The teacher explains ideas that are not linked to any school subjects; thus, the purposes do not enhance learning of organic chemistry/any school subjects	All right, so here's just a few examples of where carbon is used in the industry to make pencil leads, jewellery, the roads, the soles of our shoes, and tires.

Table 27: Codes observed in relation to the lesson episodes

Episode	Codes enacted	Code Name	For what purposes?	Role of the teacher in each episode.	Assumed role of the learners in each episode
1	PA++, RA++	Sovereign	Introduce the target content	- Give direct cues on what learners need to do. E.g ‘so let’s go to our periodic table. - Outlining the objectives.	- Use their periodic table as directed by the teacher.
	PA+, RA+	Sovereign code	Introduce prerequisite concepts and use general science skills to consolidate understanding.		
	PA−, RA−	Exotic	To give additional or extended information		
	PA− −, RA− −	Exotic	To present general knowledge		
	PA+, RA+	Sovereign	Consolidate understanding		
	PA++, RA++	Sovereign	Deepen understanding		
2	PA++, RA++	Sovereign	Deepen understanding	- Cues for learners to follow as the teacher explains “I only have single bonds as you can see here” - Teacher asks rhetorical questions that he or she answers. - Re-outlining objectives.	N/A
3	PA++, RA++	Sovereign	Consolidate understanding	- Directing learners to pause the video to work on a class activity. - Emphasising concepts through corrections. - Asking learners questions (the teacher responds to these questions)	- Pause the video and work on an activity - Work on corrections as instructed.

The translation device above shows that the OT2 managed to tap into non-target content and purposes in this lesson. Similar to OT1, there is evidence of touching on stronger positional and relational autonomy (PA++, RA++ and PA+, RA+) all the way through to weaker positional and relational autonomy (PA−, RA− and PA− −, RA− −). Before an analysis the lesson episodes, it is already explicit that OT2 also able to focus on concepts and purposes emanating in the science curriculum and knowledge is not only left at that point but incorporated with concepts and purposes emanating outside of the curriculum (everyday knowledge and other disciplines). While the translation device can highlight specific examples of instances where the teacher focused on target and non-targets, it remains unclear how the teacher shifts codes during the overall lesson hence as previously mentioned the table below highlights specific autonomy codes that the teacher taps on and also highlights the shifts in codes happening during the lesson.

One of the aspects that stands out from the episode analytical framework is the ability of the teacher to make many shifts in episode 1 as compared to episode 2 and 3. In episode 1 the teacher is able to shift between sovereign (PA+, RA+ and PA++, RA++), exotic (PA−, RA− and PA− −, RA− −) over time in the lesson, making successful shift between two codes overall. What stands out again in the table above is that in episode 2 and 3 no shifts are noted as the teacher stays within the sovereign code (PA++, RA++). Since each episode was 10 minutes, this implies that for the last 20 minutes the teacher focused primarily on knowledge practices that focused merely on the target content and purposes. Similar to OT1, the role of the teacher appears to be quite dense in relation to the learners' role. The learners' role is again assumed as what the teacher expects them to do during the lessons depends entirely on them since there is no physical assurance of whether learners are complying or not. The detailed interpretation below outlines what was happening during each episode and the aspects that influenced the shifts (in the case of episode 1) and aspects that influenced the stay in the single code (in the case of episode 2 and 3).

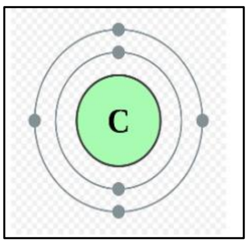
(ii) Individual lesson analysis for OT2

Episode 1

What is organic chemistry? This is a rhetorical question asked by the teacher to introduce the target content to learners. This question demonstrates strong positional autonomy (PA) and relational autonomy (RA) as learners are introduced to the target content. The question further directs learners' attention to the target content (PA++) while simultaneously laying a

foundation for learners to understand the broader concept of organic chemistry (RA++). Considering that the lesson was an asynchronous online lesson in which learners cannot directly engage in real time discussion, this question was crucial to establish an entry point to the overall development of the key concepts.
Following this, a slight weakening of PA and RA from PA++ and RA++ to PA+ and RA+ is observed as the teacher responds to the rhetorical question through explanations. These explanations led to an introduction of concepts relating to the nature of carbon which is general knowledge regarding science necessary for learners to understand given that carbon is the fundamental element in organic chemistry. At this point in time the teacher is gradually building an understanding of organic chemistry through taking a route that focuses on pre-requisite knowledge and skills. For instance, the teacher revisits the periodic table concept normally taught at grade 9. The teacher directs learners to look up for the carbon element on their periodic table to understand its group number, atomic number and mass. This step is necessary as it helps the teacher to establish extended pre-requisite concepts such as valence electrons and electron configuration taught at grade 10 level. By building on this foundation, the teacher explains why the carbon atom can form a maximum of four bonds, in this process diagrams are used to anchor explanations. At this point, understanding is still grounded in PA+ and RA+ since the concepts are the core concepts in the topic of organic chemistry. Throughout the process, the teacher poses questions to learners, although direct engagement is not possible in this context these questions aid in encouraging reflection and mental engagement with the content. The extract below highlights this instance.

TEACHER: *And as we know from grade 10, valence electrons are electrons that are found in the outermost shell of our atom. All right, so in a nutshell what we're saying is that as much as carbon has six electrons, but it has four valence electrons. And what does that mean? Right, what do those four valence electrons mean? It means that carbon can form up to a maximum of four points. So, this, what I'm highlighting here, these are our valence electrons (referring to the diagram below)*

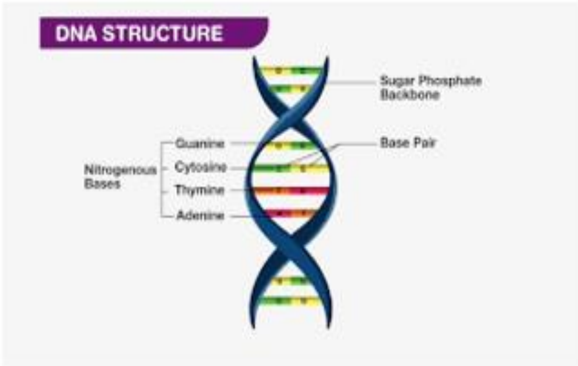


As the lesson progresses the teacher weakens PA and RA by establishing a shift from PA+ and RA+ to PA- and RA−. This shift is marked by the teacher presenting a set of reflective questions aimed at helping learners grasp the importance of the detailed explanations provided about the nature of carbon (PA+, RA+). These questions encourage learners to consider how the general scientific concepts link to broader understanding of organic chemistry. See extract below.

TEACHER: *Why are we actually studying carbon? I mean, there are so many elements on the periodic table. Why carbon? Why are we not studying nitrogen? Why are we not studying potassium? Why are we not studying calcium? What is so interesting about carbon?*

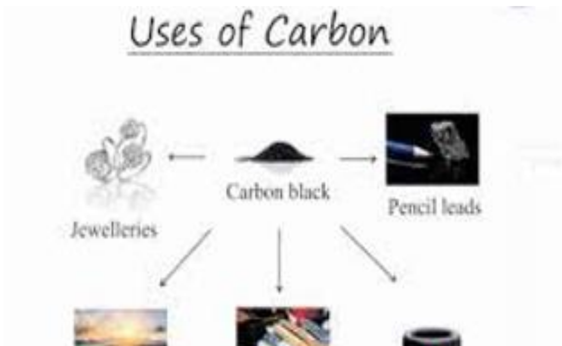
The above set of questions do not only highlight the importance of carbon nor allow learners to mentally engage with the content but also provides the teacher with an opportunity to deliver detailed explanations about the nature of carbon that extend beyond the scope of organic chemistry as prescribed by the technical science curriculum. The explanations to the questions move the teacher slightly further from the target content. The teacher extends knowledge to other disciplines, particularly biology, to create interdisciplinary engagement. By doing so, the teacher reinforces the relevance of the topic in a broader academic context. The extract below highlights this instance.

TEACHER: *So, the reason why we're studying carbon, is because carbon is the building block of life. If we look at the DNA structure itself, this is how a DNA structure looks like (Referring to the diagram below). But if we go deeper into the molecular level, you will realise that basically DNA is made up of carbon. So human beings are made up of carbon. In fact, 18% of the human body is made up of carbon. So, the sugars, the glucose, protein, and all of those, they're made up of carbon.*

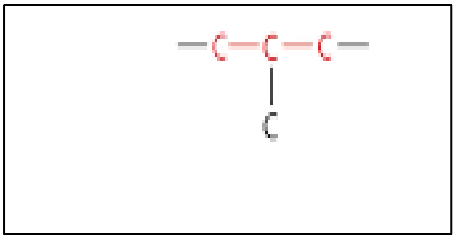


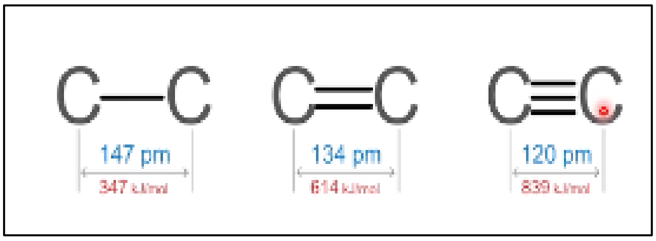
At this point in the lesson, the focus has shifted entirely into a biology lesson moving beyond the immediate scope of the target content. The teacher does not stop here but further weakens PA and RA to PA− − and RA− − where the focus is on everyday understandings of the uses of carbon. At this stage, the lesson has shifted significantly from the targets since these ideas do not directly enhance the learning of organic chemistry. See extract below.

TEACHER: *And then carbon, in its natural form, is used in jewellery. Carbon can also be used to make ink and paint. And the graphite is used as lead in our pencils. And most importantly, carbon can be used in carbon dating. All right, so here's just a few examples of where carbon is used in the industry to make pencil leads, jewellery, the roads, the soles of our shoes, and tires.*



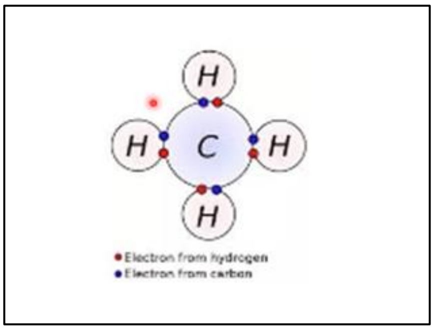
Even though the teacher detoured significantly from the targets, what is key is that explanations are not left outside of the science domain. The teacher gradually strengthens positional autonomy (PA) and relational autonomy (RA) by shifting back to PA+ and RA+. This is achieved through explanations that connected the vast everyday uses of carbon to the scientific significance. The teacher explains that carbon in general is the building block of life hence it is the focus in organic chemistry. This explanation further establishes a bridge back to the target content and purposes (PA++, RA++) as the teacher further explains the unique ability of carbon to form chains, branches and different types of bonds (single, double and triple) thus making it a core element in organic chemistry. These explanations are integral in understanding IUPAC naming and structural formulas which are the key concepts in this lesson. Below are diagrams used by the teacher to anchor explanations.



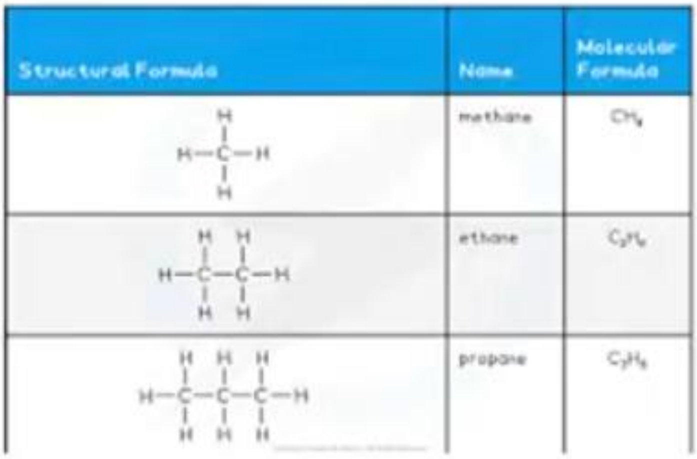


Diagrams showing different types of bonds formed by carbon

As the lesson proceeds there is a series of weakening and strengthening of PA and RA between the two codes PA+, RA+ and PA++ and RA++. Using PA+, RA+ the teacher further explains the ability of carbon to typically bond with hydrogen as a result of the abundant nature of hydrogen. At this point the teacher revisits the concept relating to the nature of carbon in which carbon forms a maximum of four bonds, a diagram is presented to anchor the explanation (see below)



The diagram above generally highlights a simple hydrocarbon thus its presentation allowed the teacher to gain entry into the target content thus establishing a shift from PA+, RA+ to PA++, RA++. Within the target content the teacher introduces the concept of hydrocarbons which is explained as organic compounds that only contain carbon and hydrogen atoms. The explanation is further extended to the ability of carbon to bond to itself and other atoms resulting into different structures called structural formulas. The teacher further uses a diagram (as shown below) to help learners visualise these structures. At this point the teacher explains concepts directly relating to the target as highlighted in the objectives of the lesson.



While explaining concepts within the target framework the teacher is very intentional about ensuring that learners follow through by giving specific cues that direct learners' attention. For example, the teacher uses statements such as "so here you can see", "as you can clearly see" making reference to aspects explained and anchored through diagrams. This creates mental engagement and establishes a conversational tone, which is important especially considering that this is an asynchronous lesson.

Episode 2

This episode builds on the ideas of the concept of structural formulas introduced in Episode 1. As indicated from Table 21, Episode 2 is characterised by a single code (PA++, RA++) indicating that the teacher is grounded within the framework of target content and purposes. Initially in this episode, the teacher highlights to learners that hydrocarbons share similarities as they all consist of carbon and hydrogen atoms. However, the names of the hydrocarbons differ due to the differences in the number and arrangement of these atoms. This explanation transitions into an introduction of the concept of IUPAC naming. The teacher begins by specifying the general rules of naming hydrocarbons, particularly guiding learners into an understanding of prefixes in IUPAC naming. These further grounds understanding within the targets as this forms part of procedures and skills that learners need to develop to understand the topic of organic chemistry. See extract below.

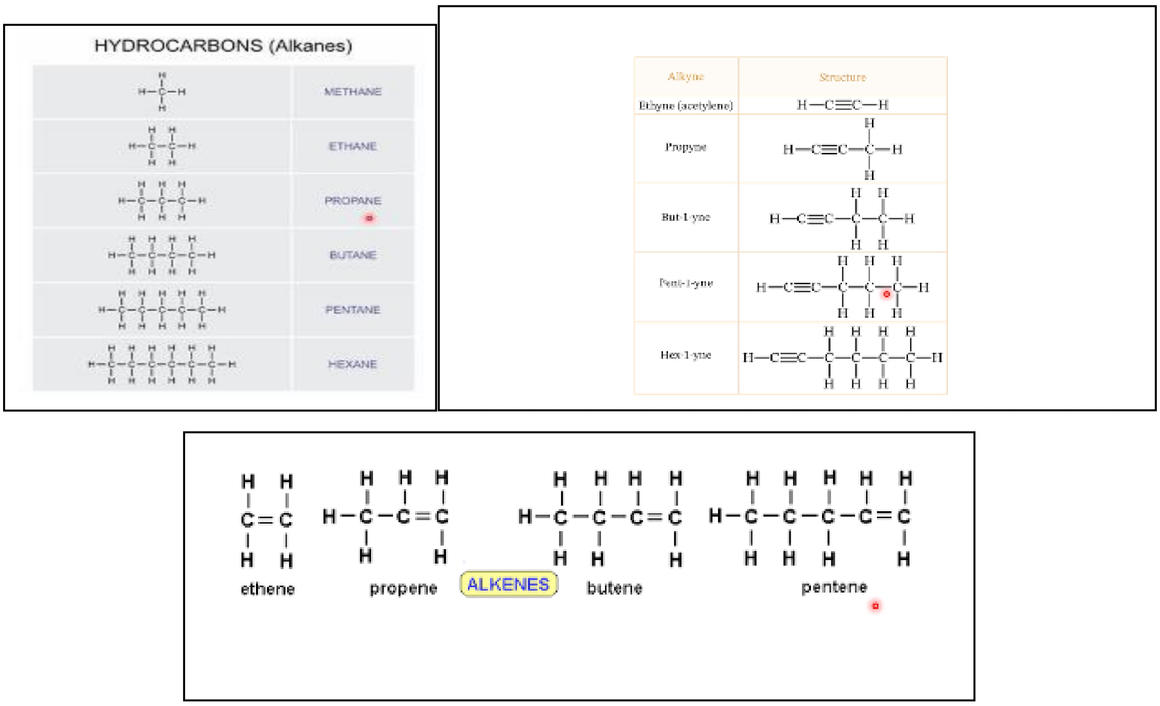
TEACHER: *If we only have one carbon, there's a myth. If there are two carbons, the root of the name, the prefix is eth. If there's three carbons, it's prop. If there's four carbons, it's but. If there's five, it's pent. If there's six, it's hex. Seven, hept. Eight carbons in the longest continuous chain, we're dealing with oct. If there's nine, it's non. If there's 10, it's dec. All right? But for the sake of technical science, we are only dealing with up to six carbon atoms in the longest continuous chain, meaning that we will never deal with a structure that has the prefix of the name as hept, all right?* (as shown in the picture below)

Number of C atoms	Root
1	Meth-
2	Eth-
3	Prop-
4	But-
5	Pent-
6	Hex-
7	Hept-
8	Oct-
9	Non-
10	Dec-

As the lesson continues the teacher further explains how suffixes are formed, detailing that the suffix depends on whether the molecule is a single, double or triple bond. This explanation leads to an understanding of the concept of a homologous series as the teacher further explains that the suffixes determine the series name. See extract below.

TEACHER: *So, if your molecule or your organic compound has only single bonds in between the carbon atoms, then the suffix of the name is going to be ane, all right? Because now the molecule is an alkane. Why do we call it an alkane? It's an alkane because it is just a hydrocarbon that has single bonds in between the carbon atoms and the rest of bonds are just hydrogen bonds. So that is an alkane, and the suffix of the name is ane, all right? Now, if it happens that in your organic compound, somewhere in between the carbon atoms, there's a double bond, then you're dealing with an alkene. The structure now belongs to the homologous group called alkenes and the name will take the suffix ene, right? The same thing goes if it happens that somewhere in the structure in between the carbon atoms, you have a* *triple bond, then that organic compound belongs to the homologous series of alkynes, then it'll take the suffix yne, all right?*

All these ideas and explanations highlight ideas from the topic of organic chemistry as prescribed by the technical sciences curriculum introduced with the aims of deepening understanding of the topic (PA++, RA++). The rest of this episode is characterised by the teacher giving detailed explanations and examples relating to IUPAC naming when the prefix and the suffix are combined for specific homologous series. In the process the teacher highlights the importance of identifying the position of the bonds as a part of general rules for understanding IUPAC naming. Diagrams as an anchor for explanations are given and in between the teacher continues giving cues and asking rhetorical questions that directs learners' attention to the lesson. Below are examples of diagrams used by the teacher in this segment.



Diagrams used to anchor explanations related to naming organic molecules.

Episode 3

Similar to Episode 2, this episode is rooted in ideas from the topic of organic chemistry as prescribed by the technical sciences curriculum (PA++) introduced for the purposes of deepening understanding (RA++). However, the focus in this episode is to consolidate understanding as learners are given a class activity which is rectified instantly before the end of the lesson. The activity requires learners to draw structural formulas for hydrocarbons thus reinforcing the concepts and skills taught throughout the lesson. Given the asynchronous nature of the lesson, learners are required to pause the video so that they can complete the task. Whether learners follow this instruction is not guaranteed, hence this is an assumed role for learners as previously mentioned.

Before addressing the corrections, the teacher says, "*All right, I believe you must be done since you're replaying the video again*". This statement highlights specific cues given to learners as an acknowledgement of the asynchronous nature of the lesson. As the lesson proceeds the teacher revisits key concepts, reiterates the main objectives, and emphasises the target skills necessary for learners to accurately draw structural formulas. For an example, the focus is on whether learners' structures highlight only four bonds around the carbon atom irrespective of whether the molecule is an alkane, alkene or alkyne. In so doing the target content and skills are sharpened thus enhancing the overall understanding of the topic of organic chemistry. In the post lesson interview the teacher justified this approach, emphasising repetition as a key method. The teacher noted that in asynchronous contexts it cannot be assumed that learners understand the concepts after a single explanation. The reinforcement of these concepts occurs at stronger positional and relational autonomy (PA++, RA++) clearly highlighting the necessity of learners mastering the disciplinary knowledge of organic chemistry.

(iii) Autonomy plane for OT2 lesson analysis

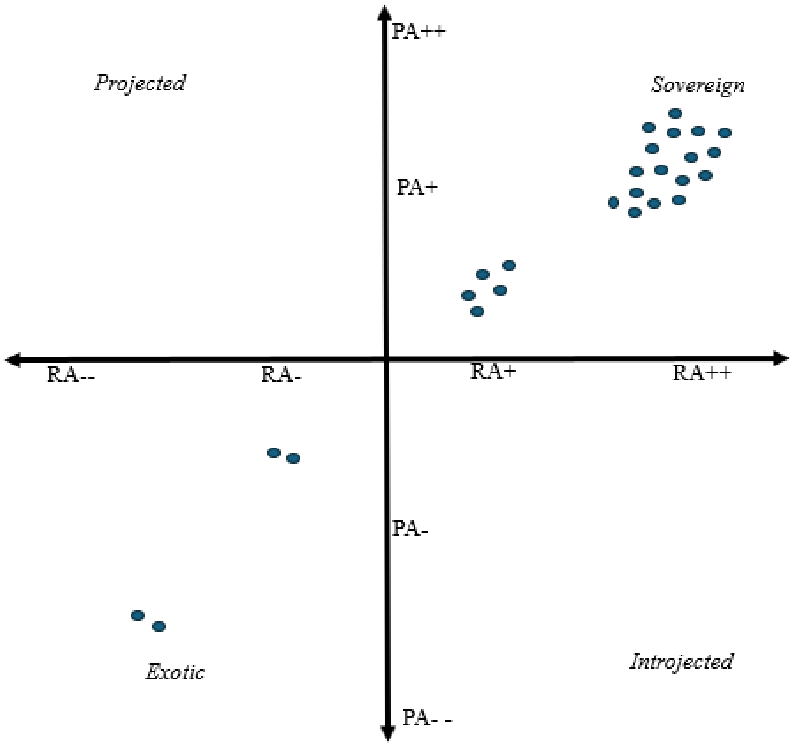


Figure 19: OT2 Autonomy plane

The overall analysis of OT2 lesson reveals an autonomy plane with which the teacher manages to make shifts between the two codes: sovereign and exotic. As indicated from the plane the teacher spends a significant amount of time in the sovereign codes. This indicates the teachers' commitment to developing learners' understanding of the scientific concepts which is a fundamental goal in the technical sciences classroom. Even though the teacher aimed to develop learners' understanding of scientific concepts, a brief shift to the exotic codes (PA−, RA− and PA− −,RA− −) is noted. These shifts serve as a strategy to connect non-target concepts and procedures, such as knowledge from other domains and everyday examples, allowing learners to perceive science as an integrated system linked to various domains. Following a detailed analysis of the lesson episodes, shifts in autonomy codes were observed only in Episode 1. For the remainder of the lesson, the teacher remained in the sovereign code thus establishing a return trip between the sovereign and exotic codes, as highlighted in the next section.

5.3.2.3. Observations made from online lessons of OT3

This lesson was approximately 30 minutes and was divided into three episodes each lasting ten minutes. The teacher specified that the primary focus of the lesson was to introduce learners to the concept of molecular formula. In addition, learners were expected to know how to derive or identify the structural formula from a given molecular formula. Moreover, the concept of saturated and unsaturated hydrocarbons was covered. Learners were also expected to define homologous series and pair them with their functional groups. Lastly, learners were expected to define and identify isomers.

(i) Translation device and episode analytical framework for OT3

The lesson appeared to be too dense, and the teacher mentioned in the post lesson interview that the focus was to teach for assessment and learners were expected to know how to tackle exam questions which is why most concepts from the topic of organic chemistry had to be covered in the 30 minutes interval. The translational device in Table 28 below highlights specific examples of positional and relational autonomy in the lesson and Table 29 shows autonomy codes tapped on in each episode.

Table 28: Positional and Relational autonomy translational device for online teacher 3 (OT3) lesson analysis

Strength	Codes (PA and RA)	1st Level Indicator	2nd Level indicator	Specific examples for OT3 lesson
Stronger	PA++, RA++	Target content and purpose	The teacher describes ideas from the topic of organic chemistry with the purposes of deepening understanding of the topic	So, lets' look at the molecular formulas. So, the molecular formula, it's a chemical formula that indicates the type of atoms and the correct number of each atom in a molecule.
	PA+, RA+		The teacher focuses on ideas that are not from organic chemistry but from the technical science curriculum in general. The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.	Before we move further, just take note of these most important things to know. The first one should always be in your mind: carbon is always surrounded by exactly four bonds.
	PA−, RA−	Non-Target content and purpose	Teachers uses ideas that are academic but are outside of the technical science curriculum and the purposes speak to other domains that are not unique to understanding organic chemistry	None observed.
Weaker	PA− −-, RA − −		The teacher explains ideas that are not linked to any school subjects; thus, the purposes do not enhance learning of organic chemistry/any school subjects	None observed.

Table 29: Codes observed in relation to the lesson episodes

Episode	Codes enacted	Code Name	For what purposes?	Role of the teacher in each episode.	Assumed role of the learners in each episode
1	PA++, RA++	Sovereign	Introduce key concepts	- Outlining of lesson objectives.	N/A
	PA+, RA+	Sovereign	To consolidate or link concepts for understanding		
	PA++, RA++	Sovereign	Deepen understanding		
2	PA++, RA++	Sovereign	Deepen understanding	- Emphasis on key objectives - Giving directives of how the lesson unfolds	N/A
	PA+, RA+	Sovereign	Consolidate understanding		
	PA++, RA++	Sovereign	Deepen understanding		
	PA+, RA+	Sovereign	Consolidate understanding		
	PA++, RA++	Sovereign	Deepen understanding		
3	PA++, RA++	Sovereign	Consolidate and deepen understanding	- Cues given for what learners need to do e.g check your notes, pause the video and work on your own. - Teacher provides solutions for the class activity. - Teacher gives homework	- Learners are required to check notes to validate responses - Learners are required to complete classwork activities by pausing the video

From the translation device above, there is evidence of knowledge forms that explain target concepts and purposes. This entails that the OT3 only focused on ideas emanating from the topic of organic chemistry (PA++) and general science knowledge (PA+). These ideas are introduced for the purposes of deepening understanding (RA++) and enhancing learning of organic chemistry (RA+). The absence of examples related to non-target content and purposes suggests that both positional autonomy (PA) and relational autonomy (RA) remained stronger throughout the lesson. Although the translational device demonstrates the teacher's consistent focus on target content and objectives, it remains essential to clearly outline how shifts between PA++, RA++ and PA+, RA+ occurred in each episode. Doing so will reveal specific conditions or practices that informed the codes enacted in this lesson. From the episode analytical framework, it remained notably that throughout all the episodes the teacher managed to make shifts between PA++, RA++ and PA+, RA+. The purposes of enacting these codes appears to be deepening and consolidating scientific understanding. Notably, the assumed role of learners is limited, as their explicit involvement is only observed in the final episode when the teacher concludes the lesson and assigns a class activity along with its solutions. In the last episode, learners are expected to pause the video and complete the tack independently. However, since this is an asynchronous lesson, the extent of their engagement remains assumed.

(ii) Individual lesson analysis for OT3

Episode 1

The lesson began with the teacher foregrounding the key objectives, clearly outlining the skills and knowledge that learners needed to grasp by the end of the lesson. Outlining of the key objectives serves as a foundation for presenting key concepts within PA++ and RA++ which represent a stronger level of positional autonomy and relational autonomy. The teacher introduced the concept of organic chemistry, thus establishing an entry point for the introduction of other related concepts. Furthermore, the concept of molecular formula and structural formula is explained. At this point, the teacher foregrounded the key skills and knowledge necessary for learners to grasp the distinction between the two concepts. For instance, the teacher stated that, *"Knowing a molecular formula doesn't mean you can predict the structural formula of a compound; it must be drawn!"* In the process diagrams are used to anchor explanations hence relational autonomy is still stronger (PA++). Additionally, concepts such as homologous series and functional groups are explained. In explaining these concepts, the teacher used technical terms which confine understanding to prescribed definitions and terminologies within the technical sciences curriculum. While this allows learners to grasp the discipline terminologies, the lack of linking knowledge to other knowledge sources such as real-world examples present limited opportunities for integrative knowledge building.

Within the ten-minute segment there is only one instance in which the teacher slightly weakens positional autonomy and relational autonomy. Such an instance was observed when the teacher explained atomic bonding in relation to carbon, hydrogen, oxygen, and halogen molecules, using a supporting diagram (as shown below). This explanation draws on general knowledge regarding science (PA+) from earlier grades within the technical science curriculum. The concept of atomic bonding serves as valuable prior knowledge for understanding organic chemistry (RA+).

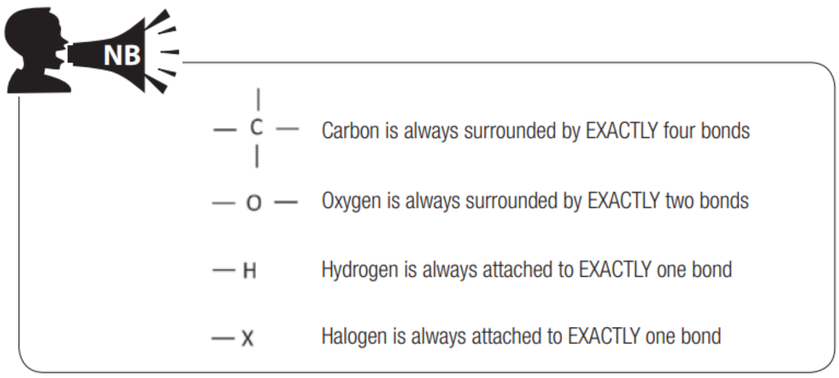


Diagram used to explain atomic bonding

While this instance briefly connects to broader scientific concepts, this episode is more confined to prescribed disciplinary content without an integration of other disciplines or real-world contexts. The teacher again strengthened PA and RA to PA++ and RA++ and resided at this level for the entire episode. A few aspects that confine the teacher within this level are noted. For example, in this episode there is limited use of rhetorical questions. Given the context, the limited use of rhetorical questions reduces the opportunities for learners to mentally engage and reflect on the content. Moreover, it constrains the teacher's ability to anticipate learners' responses thereby limiting potential shifts to other autonomy codes. For example, the teacher can anticipate learners' responses, allowing them to either weaken or strengthen positional autonomy (PA) or relational autonomy (RA) based on the assumed responses.

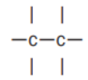
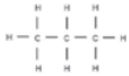
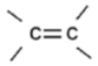
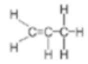
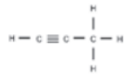
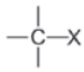
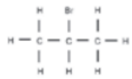
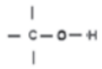
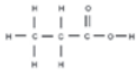
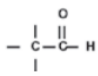
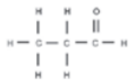
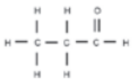
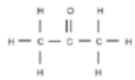
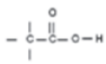
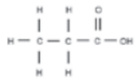
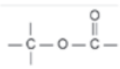
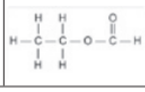
The lack of rhetorical questions in this episode further enforces passive learning since most of the teachers' explanations are outlined without considering how learners might respond.

Furthermore, within the 10 minutes segment of this episode, the teacher introduced approximately six different concepts using dense disciplinary knowledge (PA++, RA++). It may be argued that the teacher may be taking advantage of limited ability of learners to actively ask questions for clarity in a recorded lesson. In the post lesson interview the teacher mentioned that one of the goals was to ensure learners know how to respond to exam questions. While this is expected given that the teacher was teaching grade 12 learners, this approach however reinforced rote learning and confined the teacher within stronger positional and relational autonomy. Further this approach may raise concerns about the risk of cognitive overload in asynchronous lessons.

Episode 2

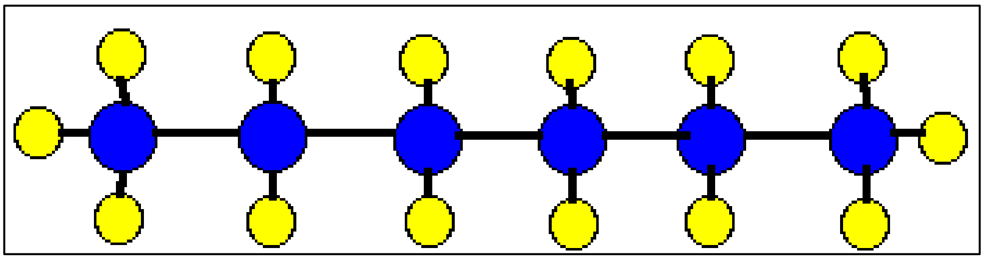
In this episode the teacher further re-emphasised the key objectives of the lesson, which is expected given the context. Providing clear directives aids learners in navigating the content effectively. This occurs at PA++ and RA++ as the teacher delved deeper into the key concepts, as highlighted in the table below. The teacher identified and elaborated on the types of homologous series, briefly discussed the general formula, and revisited the concept of functional groups, illustrating these ideas with specific examples from the table. At this instance, the teacher is focused on ideas emanating directly from the topic of organic chemistry as prescribed through the technical sciences curriculum (PA++) with the aim of deepening understanding of these concepts (RA++). This focus reflects stronger positional autonomy and relational autonomy highlighting a stronger focus on the target content and purposes.

Classification of organic molecules according to homologous series

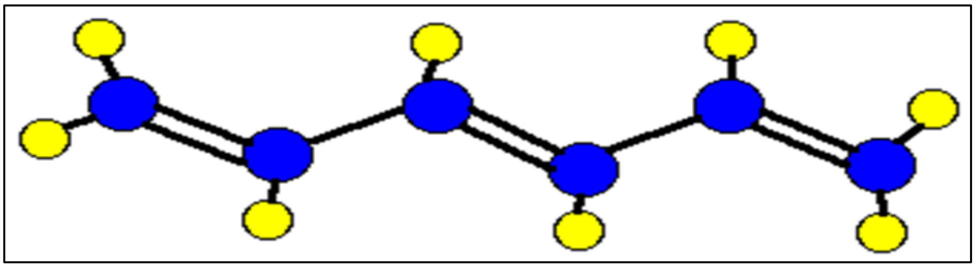
	Homologous series	General formula	Functional Group	Suffix	Example name	Structural formula	Condensed structural formula	Molecular formula
Hydrocarbons	Alkanes	C_nH_{2n+2}		-ane	propane		$CH_3CH_2CH_3$	C_3H_8
Hydrocarbons	Alkenes	C_nH_{2n}		-ene	propene		$CH_2{=}CHCH_3$	C_3H_6
Hydrocarbons	Alkynes	C_nH_{2n-2}	$-C{\equiv}C-$	-yne	propyne		$CH{\equiv}CCH_3$	C_3H_4
Haloalkanes/ alkyl halides		$C_nH_{2n+}1X$ (X = F, Cℓ, Br, I)		-ane	2-bromopropane		$CH_3CHBrCH_3$	C_3H_7Br
Alcohols		$C_nH_{2n+1}OH$		-ol	propan-2-ol		$CH_3CHOHCH_3$	C_3H_7OH
Aldehydes		$C_nH_{2n}O$ n =1, 2, ...		-al	propanal		CH_3CH_2CHO	C_3H_6O
Ketones		$C_nH_{2n}O$ n = 3, 4, ...		-one	propanone		CH_3COCH_3	C_3H_6O
Carboxylic acids		$C_nH_{2n}O_2$ n = 1, 2, ...		-oic acid	propanoic acid		CH_3CH_2COOH	$C_3H_6O_2$
Esters		$C_nH_{2n}O_2$ n = 2, 3, ...		-oate	ethyl methanoate		CH_3CH_2OOCH	$C_3H_6O_2$

In the process, the teacher weakened PA and RA from PA++ and RA++ to PA+ and RA+ when explaining the bonding of oxygen to carbon in functional groups such as alcohols and carboxylic acids. At this point, the concept of atomic bonding between carbon and oxygen is revisited to help learners consolidate their understanding. This is general knowledge regarding science introduced to enhance learning of organic chemistry. Immediately following this, the teacher strengthened PA and RA by establishing a shift back to PA++, RA++. The focus is on suffixes which are explained as important in identifying names of organic compounds. The teacher further explained how learners can write condensed structural formulas by emphasising that learners "*should write what they see*" while providing extended details using an alkane example from the table. This instance highlights necessary skills required for learners to successfully grasp procedures relating to identifying structural formulas. In addition, the teacher explained prefixes as being determined by the number of carbon atoms, for example, four carbons = butane.

As the lesson proceeded new concepts such as saturated and unsaturated hydrocarbons are introduced. At this point, the teacher again weakened PA and RA by establishing a shift to PA+, RA+. The concept of atomic bonding, particularly for carbon, is revisited to emphasise the structural differences between saturated and unsaturated hydrocarbons as seen in the diagrams below.



Saturated hydrocarbon



Unsaturated hydrocarbon

Following this distinction, a shift to PA++, RA++ is observed as the teacher explained the differences in these structures using technical terms. The concept of isomers is also introduced and defined with specific examples. Even though shifts between PA++, RA++ and PA+, RA+ (or vice versa) are observed, the lesson remains primarily focused on the target content and purposes. This makes the lesson highly centred on stronger PA and RA with no instances of significantly weakening PA and RA to create entry points for learners to engage with and construct an understanding of the scientific knowledge from other knowledge sources. Within the 10 minutes interval, the teacher introduced multiple concepts. This positions learners primarily as passive consumers of knowledge. This observation was based on the number of distinct organic chemistry concepts introduced within a short time frame, as noted during lesson analysis and later confirmed in the teacher interview, where the teacher explained that time constraints influenced the density of content covered. The role of learners in this episode is limited as they are not actively interacting with the content. Given that the lesson is too dense in key concepts, incorporating reflective learning opportunities within this context would have fostered active participation. In turn, this would have enabled the teacher to respond to learners' assumed needs in relation to the content, allowing pedagogical adjustments in real time or through planned reflection. The data from CT2, for instance, showed that learner interaction served as a critical trigger for reflective action thus prompting the teacher to weaken or strengthen positional autonomy (PA) and relational autonomy (RA) in response to learners' understanding. In the context of this asynchronous online lesson, where real-time participation was not possible, assumed reflective pedagogy (that is, anticipating learners' likely areas of confusion and intentionally planning moments for conceptual reinforcement) could have supported similar integrative shifts. Such anticipatory reflection, as seen in OT1 and OT4, could have allowed the teacher to structure content in ways that maintain conceptual coherence while still promoting integrative knowledge building even in the absence of direct learner feedback. Doing so would also enable the teacher to respond to learners' assumed needs in relation to the content thus, potentially facilitating shifts to other codes. It is important to note that the interplay between learners' assumed participation and reflective teaching can together create the conditions necessary for autonomy shifts to occur, thereby fostering integrative knowledge building.

Episode 3

Episode 3 is a direct continuation of the concept of isomers, which the teacher initially introduced within the PA++, RA++ code in Episode 2. Throughout the episode the teacher stayed within stronger PA and RA thus maintaining a target content focused approach. The teacher expanded on the concept of isomers and used the diagram below to clearly distinguish between positional, functional, and chain isomers.

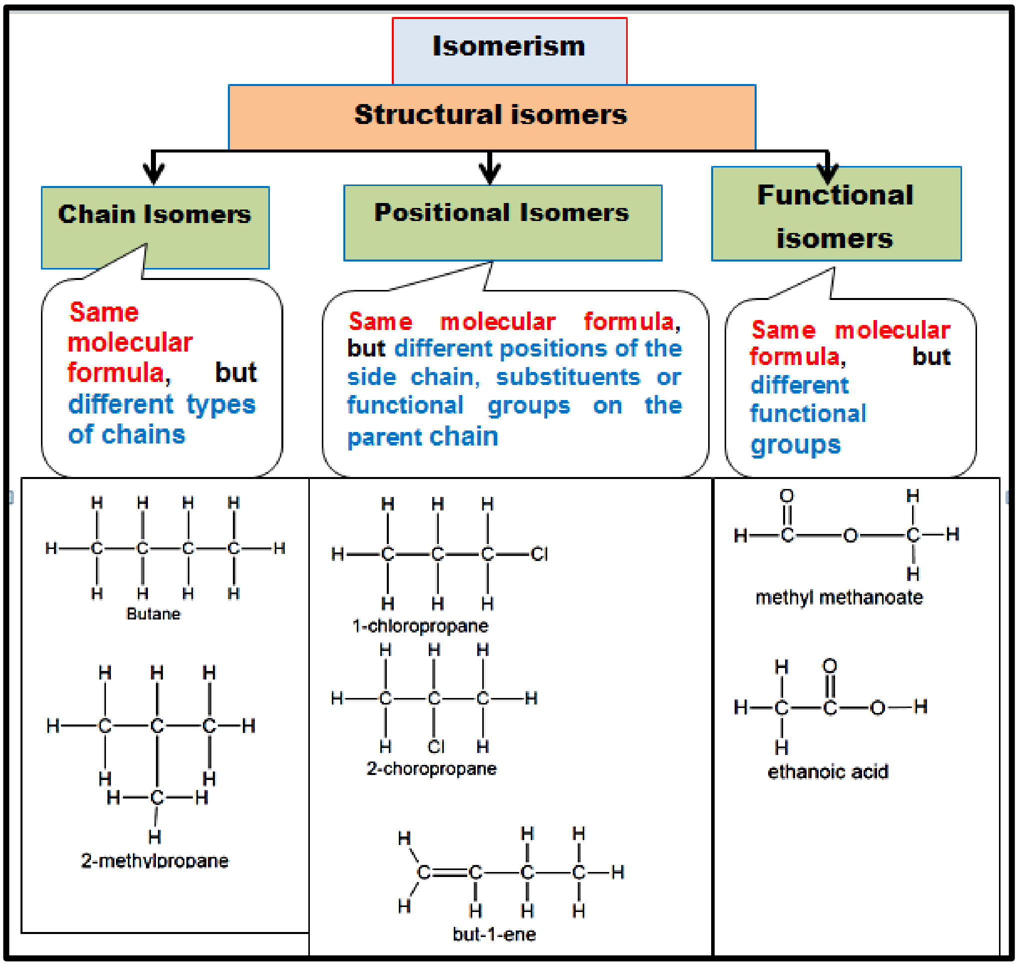


Diagram showing different types of isomers

In this episode skills relating to identifying different isomers based on the different types of chains, positions of the side chain and different functional groups are reinforced. For example, the teacher mentioned:

TEACHER*: As I have explained that the chains we are focusing on is the longest chain, which is formed by the carbon element. If we can look at the first one (referring to the diagram above), on the chain isomer, when I look at the first structure that I am having, it has 4C, which is the carbons. And if I were to quickly count the hydrogens, they will take me to 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. It has 10 what? Hydrogens. And its name, its IUPAC name will be the butane.*

But when you look at the structure below there, the structure below there, it differs. It's different from the structure that we just observed now, which is the butane. When I look at the next one, yes, when I count the number of carbons, it's 1, 2, 3, 4, which is the same number as *the previous diagram. And when I count the hydrogens, I also get 10. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. I also get 10. So, the molecular formula for both structures is the same. But when I look at the structure, they are different. The first one is just a one long straight chain. But when I look at the next diagram, it has a what? A branch, which will automatically affect the IUPAC name. So that's how we see a chain isomer. This molecular formula is the same, but when you look at the structures there, it will be different.*

Following this extract, the teacher further elaborated on positional and functional group isomers, using the same principles. The above diagram is continually used to anchor explanations. The teacher further addressed the naming of the isomers thus reinforcing the concept of IUPAC naming which is integral in organic chemistry. Compared to the other episodes, this episode demonstrated some learner engagement, as the teacher directs learners to pause the video and work on specific content-related questions. Additionally, learners are tasked with completing a class activity, which is then rectified on the spot after the teacher assumed they have completed it. Even during the correction phase, the teachers' explanations maintained stronger PA and RA (PA++, RA++) thus reinforcing the focus on the target content and purposes. Despite the inclusion of brief engagement opportunities, the nature of the interactions was insufficient to result in significant shifts in autonomy codes. For example, the process of working on corrections took a traditional approach, in which the teacher simply provided learners with the correct responses without adequately allowing for mental engagement or reflection on their own thoughts in relation to the content. While the inclusion of learner engagement activities represented a positive step, the absence of meaningful shifts in autonomy codes highlights the need for intentional practices that promote integrative knowledge building in asynchronous contexts.

(iii) Autonomy plane for OT3 lesson analysis

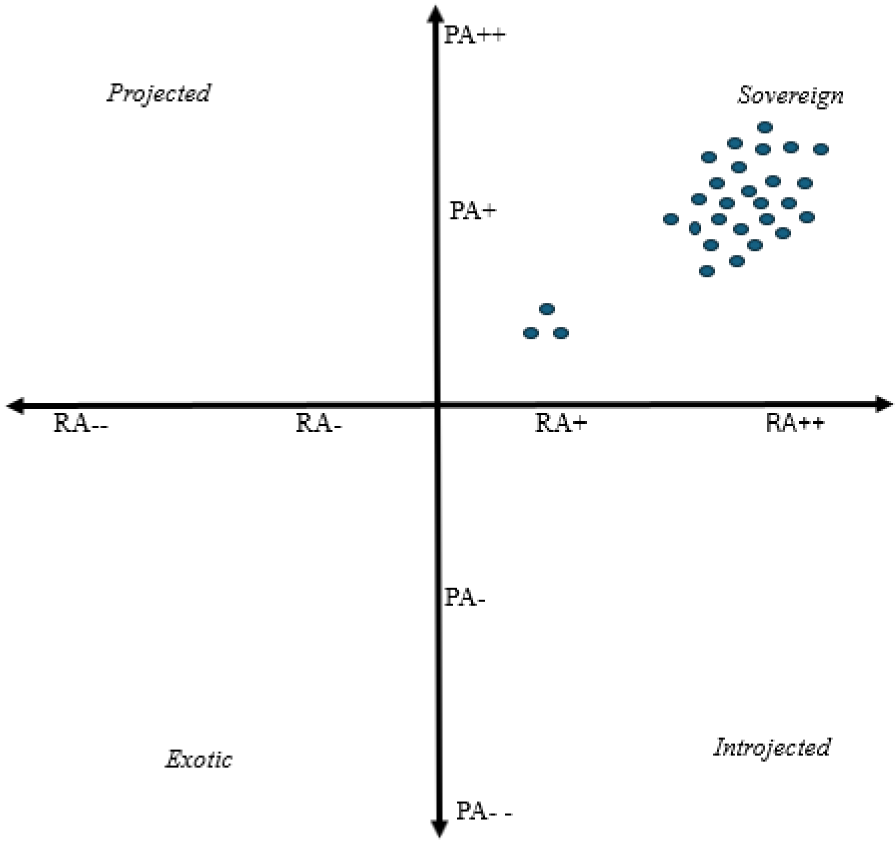


Figure 20: OT3 Autonomy plane

The autonomy plane of OT3 indicates that the teacher resided within a single code (sovereign code) throughout the lesson. This indicates a strong focus on ideas with a high level of positional autonomy and relational autonomy. While there are a few instances where the teacher slightly weakened PA and RA to PA+ and RA+, these shifts remain aligned with the lesson's targets thus offer limited opportunities for interdisciplinary learning. From the plane, there is no evidence of the teacher shifting to other codes such as projected, exotic, or introjected. This suggests a limited integration of diverse knowledge forms and a teaching approach that focuses on subject centric ideas. The lack of shifts to other codes reveals the inability of the teacher to venture out to other sources that may contribute to overall learning of organic chemistry. Such a practice hinders opportunities for integrative knowledge building.

5.3.2.4. Observations made from online lessons of OT4

This lesson was as an introductory lesson to organic chemistry. The aim of the lesson was to equip learners with an understanding of key concepts such as organic molecular structures and formulae as well as IUPAC naming of organic compounds. At the beginning of the lesson the teacher outlined that the focus was specifically on alkanes, by stating that, "*For today, we'll be focusing on alkanes along with their naming*". Furthermore, the teacher covered the concepts relating to structure and physical properties of alkanes in details.

(i) Translation device and episode analytical framework for OT4

This lesson was well structured with clear objectives outlined from the beginning and well followed through in the overall lesson. Similar to OT1, OT2 and OT3, this lesson lasted 30 minutes and was divided into three episodes. Furthermore, the translation device in Table 30 highlights specific examples of positional and relational autonomy as demonstrated in the lesson. To clearly highlight how the enactment of these codes occurred in this lesson, Table 31 is necessary as it shows codes enacted in each episode along with the purposes and conditions for this enactment including the role of teacher and the learners.

Table 30: Positional and Relational autonomy translational device for online teacher 4 (OT4) lesson analysis

Strength	Codes (PA and RA)	1st Level Indicator	2nd Level indicator	Specific examples for OT2 lesson
Stronger	PA++, RA++	Target content and purpose	The teacher describes ideas from the topic of organic chemistry with the purposes of deepening understanding of the topic	We have the molecular formula, which indicates the actual number of atoms of each element making up the compound. We have the structural formula, which shows all the atoms and bonds in a molecule.
	PA+, RA+		The teacher focuses on ideas that are not from organic chemistry but from the technical science curriculum in general. The purpose is to use knowledge of other topics within the science curriculum to learn about organic chemistry.	As such, you can note that carbon is always surrounded by exactly four bonds. Why? This is because carbon in its natural form, it has only four electrons that can be shared under the covalent bonding with other atoms
	PA−, RA−	Non-Target content and purpose	Teachers uses ideas that are academic but are outside of the technical science curriculum and the purposes speak to other domains that are not unique to understanding organic chemistry	So, we have primary carbons, which are those carbons attached to one other carbon or that are bonded to one other carbon. We have secondary carbons, which are carbons that are bonded to two other carbons. Tertiary carbons, which are those that are attached to three other carbons.
Weaker	PA− −, RA − −		The teacher explains ideas that are not linked to any school subjects; thus, the purposes do not enhance learning of organic chemistry/any school subjects	Before going into detail with regards to this topic, it is important to note that in our daily lives, organic compounds are found in the food that we eat, the gasoline that we use for our cars and so on, the medicine and drugs, the detergents that we use at home to make. They also used to make plastics and the rubber that we often find within our daily activities.

Table 31: Codes observed in relation to the lesson episodes

Episode	Codes enacted	Code Name	For what purposes?	Role of the teacher in each episode.	Assumed role of the learners in each episode
1	PA− −, RA− −	Exotic	Laying the foundation using common understanding	- Outlining the objectives.	- Follow through the lesson using given cues.
	PA++, RA++	Sovereign	Introduce key concepts		
	PA+, RA+	Sovereign	Consolidate understanding through outlining prior concepts		
	PA−, RA−	Exotic	To expand knowledge		
	PA++, RA++	Sovereign	Deepen understanding		
2	PA++, RA++	Sovereign	Deepen understanding	- Emphasis of key objectives - Teacher asks rhetorical questions that he or she answers.	- Follow through the lesson using given cues. - Pausing the video to work on specific tasks.
	PA−, RA−	Exotic	Expand knowledge		
	PA++, RA++	Sovereign	Deepen understanding and skills		
3	PA++, RA++	Sovereign	Deepen understanding and emphasise target skills	- Re-emphasises concepts - Consolidates understanding through following on the lesson objectives - Gives a conclusion to the lesson	- Follow through the lesson using given cues.
	PA++, RA−	Projected	Link mathematical procedures		
	PA++, RA++	Sovereign	Deepen understanding		

The translation device above illustrates specific examples from target and non-target content and purposes in the overall lesson. The teacher was able to tap into ideas from the topic of organic chemistry for deepening understanding of that topic (PA++, RA++). Again, there is visibility of example emanating from ideas general science knowledge introduced for the purposes of learning about organic chemistry (PA+, RA+). There is also evidence of examples that speak to knowledge that is outside of the technical science (PA−, RA−). Finally, there is evidence of knowledge forms that speak to everyday knowledge which has little to do with the teaching and learning of organic chemistry (PA− −, RA− −).

The ability of the teacher to tap into all the levels of positional and relational autonomy reveals strategic weakening and strengthening of positional and relational autonomy over time in the lesson. This strategic movement was further supported by the interview data, where the teacher explicitly indicated a deliberate intention to integrate multiple forms of knowledge. As the teacher explained, "the concept of using different forms of knowledge is not a foreign concept, I believe I have managed to integrate everyday knowledge or concepts. This is evident as I attempted to make learners aware of the uses of organic compounds in their daily lives." This reflection suggests that the shifts observed in the lesson were not incidental but rather informed by the teacher's conscious effort to connect disciplinary content with learners' everyday experiences, thereby fostering integrative knowledge building.

The episode analytical framework (Table 31) also highlights successful shifts between three codes namely, exotic, sovereign, and projected throughout the lesson. This demonstrates effective integration of both non-target and target content in overall lesson. In some episodes, there are repeated shifts within the same code. In episode 1 for example, the exotic code is accessed at different levels (PA− −, RA− −, and PA−, RA−). The teacher taps into these codes to expand knowledge or lay a foundation for the learning of target content. Notably, the table emphasises the teacher's role across all episodes, whereas the learners' assumed role remains quite limited. The following analysis explores the dynamics and practices that facilitated these observed shifts within the lesson.

(ii) Individual lesson analysis for OT4

Episode 1

As expected in asynchronous settings, the lesson began with the teacher outlining key objectives of the lesson. This sets the tone for the lesson, ensuring that learners understand the expectations in relation to the content. The outlining of the key objectives in this lesson established a foundation that enabled the teacher to link the targets to real life examples. As a result, the lesson begins with weaker positional autonomy (PA −−) and relational autonomy (RA−−). In this instance the focus was on everyday knowledge that learners may bring into the learning environment. While these do not directly enhance the learning of organic chemistry, they served as a bridge for link-making or as a foundation for introducing target content, ensuring a smooth transition into the targets. In establishing this shift, the teacher stated that:

"*Before going into detail with regards to this topic, it is important to note that in our daily lives, organic compounds are found in the food that we eat, the gasoline that we use for our cars and the medicine and drugs, the detergents that we use at home. They also used to make plastics and the rubber that we often find within our daily activities.*

The statement above highlights the relevance of organic chemistry in learners' daily lives. This link helps learners understand the practical applications of the subject matter. While the examples given are important to establish an entry point into the learning of target concepts, it is important to note that this knowledge is further from the targets. To bring the knowledge closer to the topic of organic chemistry, it is imperative that the teacher connects the everyday knowledge to the lessons' targets. One way the teacher achieved this was by posing rhetorical questions that prompted learners to reflect on what organic chemistry is - based on its applications.

The questions encouraged learners to reflect and mentally engage with the content given the inability to respond in real time. Furthermore, the questions acted as a strategic practice allowing the teacher to gradually strengthen PA and RA. At this instance a shift from PA−−, RA−− to PA++, RA++ is noted and the focus was on ideas from the topic of organic chemistry. The teacher explained that organic chemistry is a branch of chemistry that deals with the study of carbon compounds. As the teacher further unpacked what organic chemistry is, pre-requisite concepts from previous grades are revisited thus marking a shift to PA+ and

RA+. By revisiting general knowledge regarding science, the teacher bridged prior scientific understandings with the specialised concepts of organic chemistry. The following extract illustrates such an instance.

TEACHER: *So, the organic compounds that we're going to study under these topics consist of the carbon, the hydrogen, the oxygen, together with the halogens, which are often represented as X, and they are found on group 17 on your periodic table. They are only the first six of group 17, non-metals. Just as we continue with our lesson, it is important to incorporate what you've learned from grade 10 and 11 into this lesson. As such, you can note that carbon is always surrounded by exactly four bonds. Why? This is because carbon in its natural form, it has only four electrons that can be shared under the covalent bonding with other atoms. Right. It has only four electrons in its valence outer share. So does oxygen, but then oxygen has exactly two bonds, hydrogen one bond, and every halogen is always attached to exactly one bond.*

From the above extract, the teacher integrated concepts from previous grades, such as the nature of carbon and its bonding, to reinforce and expand students' understanding. By revisiting these foundational ideas, the teacher strengthened the conceptual bridge between prior knowledge and new learning in organic chemistry. In the process questions such as why carbon is always surrounded by four bonds is posed to the learners. Although learners cannot respond to this question in real time, the deliberate pause after posing the question encourages them to engage in reflective thinking before the teacher proceeded.

Understanding was not confined to slightly stronger positional autonomy (PA+) and relational autonomy (RA+); instead, the teacher strategically weakened autonomy by shifting to PA− and RA−. At this stage, the focus moved to academic concepts that, while relevant, fall outside the technical science curriculum. The teacher covered knowledge relating to different types of carbons such as primary, secondary and tertiary - which fall under the physical sciences curriculum. Using the diagrams below, explanations were anchored.

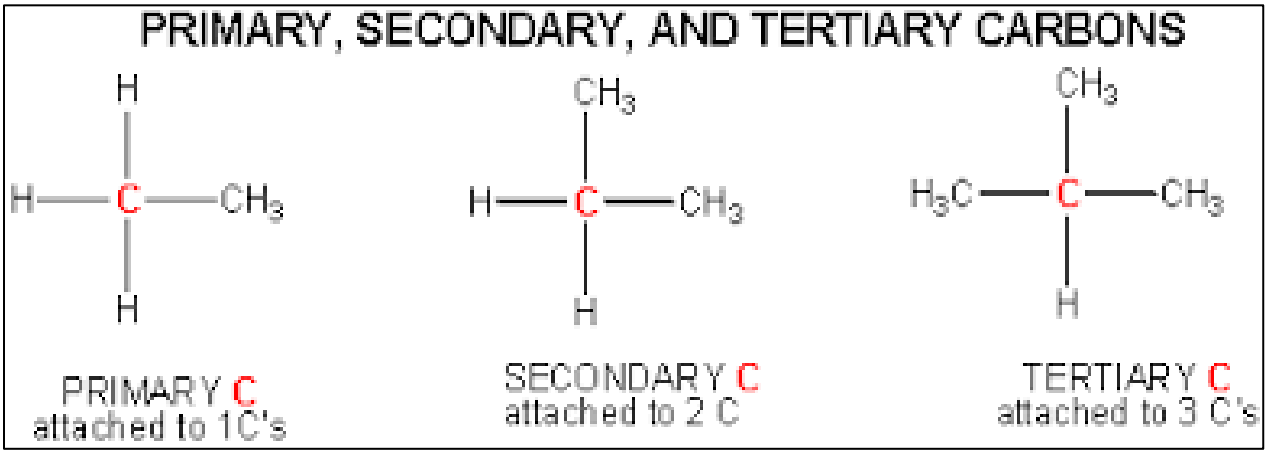


Diagram used to anchor explanations relating to types of carbons

Although this knowledge extends beyond the target content and purposes, it aids in preparing learners for a deeper understanding of molecular structures of organic compounds. Again, understanding is not left at this point, the teacher further strengthened autonomy, shifting back to PA++ and RA++, by focusing on the concept of hydrocarbons, which is directly linked to the diagram above. The series of weakening and strengthening of PA and RA in this episode enabled the teacher to make repeated shifts between different levels of autonomy thus ensuring a progressive yet structured integrative knowledge building process. In this asynchronous lesson, these shifts in autonomy are facilitated by several teaching practices such as prior knowledge activation, use of rhetorical questions and deliberate pauses to allow for reflections from learners. Although the learners' roles remain implicit in this episode, the teacher's deliberate choices in teaching practices creates an environment where autonomy shifts occur successfully and meaningfully, ensuring an effective transition through different forms of knowledge.

Episode 2

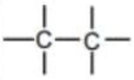
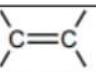
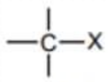
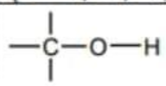
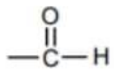
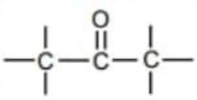
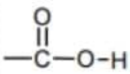
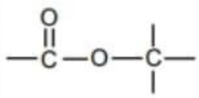
Following the introduction of hydrocarbons in episode 1, the teacher mentioned that the focus in grade 12 is on saturated and unsaturated hydrocarbons. To reinforce this concept, the teacher posed rhetorical questions that prompted learners to reflect on the distinguishing of these hydrocarbons. Since the focus is on key concepts on the topic of organic chemistry, the teacher maintained stronger positional autonomy (PA++) and relational autonomy (RA++). The extract below highlights such an instance.

TEACHER: *What's the difference? What do you think the difference is? Think about it! Saturated carbons are those that are containing only single bonds between the carbon-to-*

carbon bond. And then with unsaturated hydrocarbons, we're having those double and triple bonds between the carbon atoms.

For a prolonged period in this episode, the teacher remained at stronger positional autonomy (PA++) and relational autonomy (RA++). The emphasis was placed on key concepts such as homologous series, functional groups, general formula, condensed structural formula, and molecular formula. The prolonged focus on these concepts appeared to be intentional as the teacher explicitly stated that, "*These are basic terms that you need to know in organic chemistry*" (addressed to learners). This ensured that learners developed a strong conceptual understanding of organic chemistry which aligned with the overall purposes of the lesson. Furthermore, the teacher extended the concept of homologous series by marking it as an integral concept in this lesson. The discussion was then centred on identifying different homologous series, understanding their structures, and applying the IUPAC naming. The teacher specifically highlighted that the focus would be on alkanes as a homologous series. To support learner engagement, the teacher maintained a conversational tone which is necessary to prompt learners to reflect on the concepts being introduced rather than passively receiving information. The extract below illustrates such an instance.

TEACHER*: The third strand of our lesson goes back to the organic molecular structures. Right! We will find the differences between the homologous series, how they are structured and how you would name them. Right? Here we're having nine homologous series that are prescribed for grade 12 (referring to the diagram below)*

Homologous series	Structure of functional group	
	Structure	Name/Description
Alkanes		Only C-H and C-C single bonds
Alkenes		Carbon-carbon double bond
Alkynes		Carbon-carbon triple bond
Haloalkanes	 (X = F, Cℓ, Br, I)	Halogen atom bonded to a C atom in an alkane
Alcohols		Hydroxyl group bonded to a saturated C atom
Aldehydes		Formyl group
Ketones		Carbonyl group bonded to two C atoms
Carboxylic acids		Carboxyl group
Esters		-

We're having the alkanes, alkenes, alkynes, haloalkanes, alcohols, aldehydes, ketones, carboxylic acids, and esters. As we proceed with these series of lessons, we'll get to know the differences between these homologous series together with their structures. But for today, we'll be focusing on alkanes together with the naming of the alkanes.

After an extended period of explaining the table above, the teacher weakened PA and RA by establishing a shift to PA− and RA−. This shift signalled a transition from organic chemistry related concepts to knowledge outside of the scope of the targets. The teacher provided a brief historical background of IUPAC naming thus allowing learners to gain insight into a broader scientific and historical context. See extract below.

TEACHER: *As previously said, that we place our focus on the alkanes for this introductory lesson. So, we're having the IUPAC simply translates to the International Union of Pure and Applied Chemistry. So, this union is used or rather it was formed to make clear of the nomenclature used within chemistry together with applied chemistry. IUPAC was formed in*

1919 by chemists from industry and academia, who recognized the need for international standardization in chemistry. The nomenclature gives us ways on how to name organic compounds. To know more you can look up the history and the specific inventors of the internet, actually you can pause the video and do it now.

The extract above highlights a focus on scientific history which is further from the target content and purposes. This knowledge is necessary for learners see chemistry as an evolving discipline rather than just a set of naming rules. Additionally, the teacher encouraged independent learning by prompting learners to research the history of IUPAC naming. Learners are directed to pause the video and explore further. Doing so, fosters learner participation which is valuable in asynchronous settings. The conversational tone and interactive phrases, such as "*actually, you can pause the video and do it now*," created a sense of real time engagement which was critical in maintaining a stay within slightly weaker PA and RA.

While providing historical context is valuable, the teacher must ensure a return to the target content to prevent the lesson from becoming a scientific history session. Fortunately, the teacher effectively strengthened positional autonomy (PA) and relational autonomy (RA) by shifting to PA++, RA++. At this stage, the focus was on IUPAC naming rules, specifically addressing suffixes and prefixes. To deepen understanding, the teacher provided specific, content-related examples. This reinforced key concepts and ensured alignment with the lesson objectives, as highlighted in the extract below.

TEACHER*: So, one thing that you should know is that organic compounds should contain a prefix, the root together with the suffix. So, with the prefix, we're having the positions and the name of substituents, the side chain listed alphabetically. The root, we're having the number of carbon atoms in the main carbon chain, which is your parent chain. Then the suffix is determined by the homologous series. For instance, for alkanes, you just write an ane, which is your A-N-E. For alkenes, it's E-N-E, which is your ene. For aldehydes, it's al, etc. For alcohol, it's al, and so on. Referring to the diagram below.*

Prefix:	Root:	Suffix:
Position and names of substituents (side chains), listed alphabetically.	Number of C-atoms in the main C-chain. 1-meth- 2-eth 3-Prop but for now know 1&2	Determined by the homologous series. albane- ane Albene- ene aldehydes- al etc.

Diagram used to emphasise IUPAC naming rules

Episode 3

This episode was characterised by shifts between PA++, RA++ and PA++, RA−. At the beginning and for the majority of the episode, the teacher focused on reinforcing skills related to IUPAC naming, using alkanes as specific examples since it was the focus. This knowledge was marked by stronger PA and RA (PA++, RA++), as IUPAC naming and its rules form part of concepts and skills that learners need to know in organic chemistry. Using the table below, the teacher provided a step-by-step guideline of how learners can successfully name alkanes. At this instance relational autonomy is stronger since the procedures enforced in the lesson are targets related. Throughout the process, the teacher clearly reinforces the lesson objectives, making it easy for learner to follow. Given the asynchronous nature of the lesson, constantly emphasising the objectives grounded the teacher within the target content and purposes.

n	Name	Formula	Structural Formula
1	Methane	CH_4	CH_4
2	Ethane	C_2H_6	H_3C-CH_3
3	Propane	C_3H_8	H_3C-CH_2-CH_3
4	Butane	C_4H_{10}	H_3C-CH_2-CH_2-CH_3
5	Pentane	C_5H_{12}	H_3C-CH_2-CH_2-CH_2-CH_3
6	Hexane	C_6H_{14}	H_3C-CH_2-CH_2-CH_2-CH_2-CH_3
7	Heptane	C_7H_{16}	H_3C-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3
8	Octane	C_8H_{18}	H_3C-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3
9	Nonane	C_9H_{20}	H_3C-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3
10	Decane	$C_{10}H_{22}$	H_3C-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-CH_3

As the lesson progressed, the teacher established a shift to PA++ and RA−, indicating the weakening of relational autonomy. At this point, the focus was on using mathematical procedures to explain how the general formula for alkanes is derived. The extract below highlights this instance.

TEACHER*: From the description in the slide that we previously encountered, it is important that for you grade 12s, you notice that the alkanes follow a certain general formula, right? So, the n on that formula represents the number of carbons, right? So, if you had one carbon for n, you would just substitute one. If you had two carbons for n, you'd substitute two. If you had three, you'd substitute three. Referring to the general formula below.*

$$\boxed{C_nH_{2n+2}}$$

For instance, for methane, you know that it's $C_1H_2 \times 1 + 2$ *right? So, it would refer to C1, that you have one carbon, but then for Hs, since it's two times one, then it gives you two plus two, it means you to four. Therefore, the total when writing it, it will be* C_1H_4 *to showcase that it is a methane, and so on with others. This is basic mathematics good people!*

The teacher highlighted that this is mathematical procedures but what is key is that understanding was not left at this point. A shift back to PA++, RA++ was noted as the teacher strengthened RA. At this point, focus was placed on understanding physical properties of alkanes such as boiling point and melting point. The teacher highlighted the physical properties depended on the structure of the alkanes. This knowledge explained key ideas in organic chemistry (PA++) that was introduced to deepen understanding of the topic (RA++). A conversational tone is maintained even in this episode, thus facilitating shifts in autonomy codes.

(iii) Autonomy plane for OT4 lesson analysis

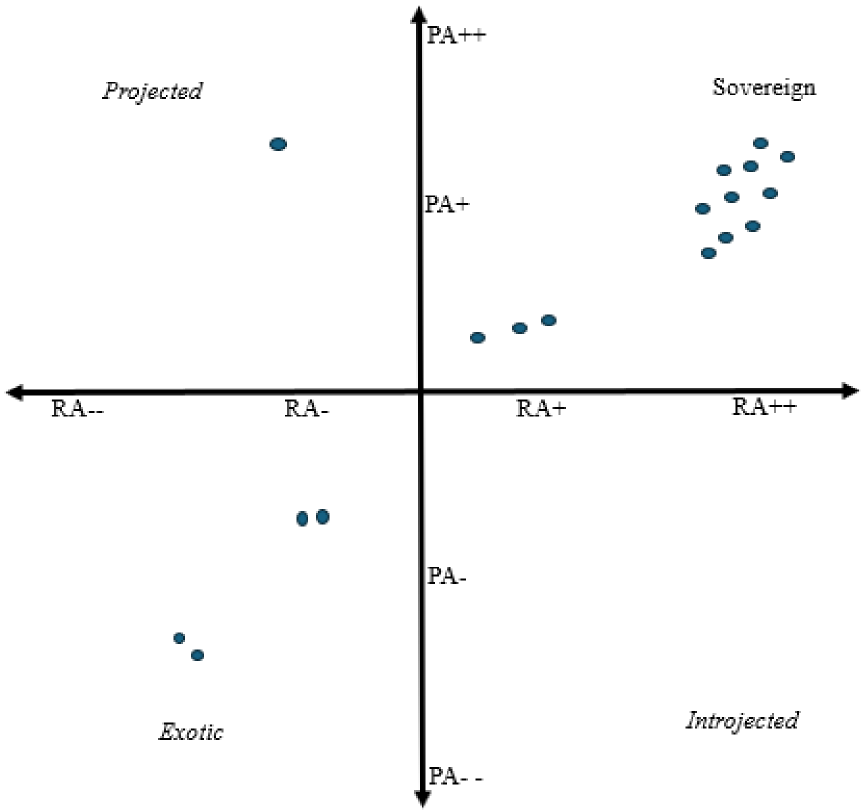


Figure 21: OT4 Autonomy plane

5.3.2.5. Summary of observations made from online lessons

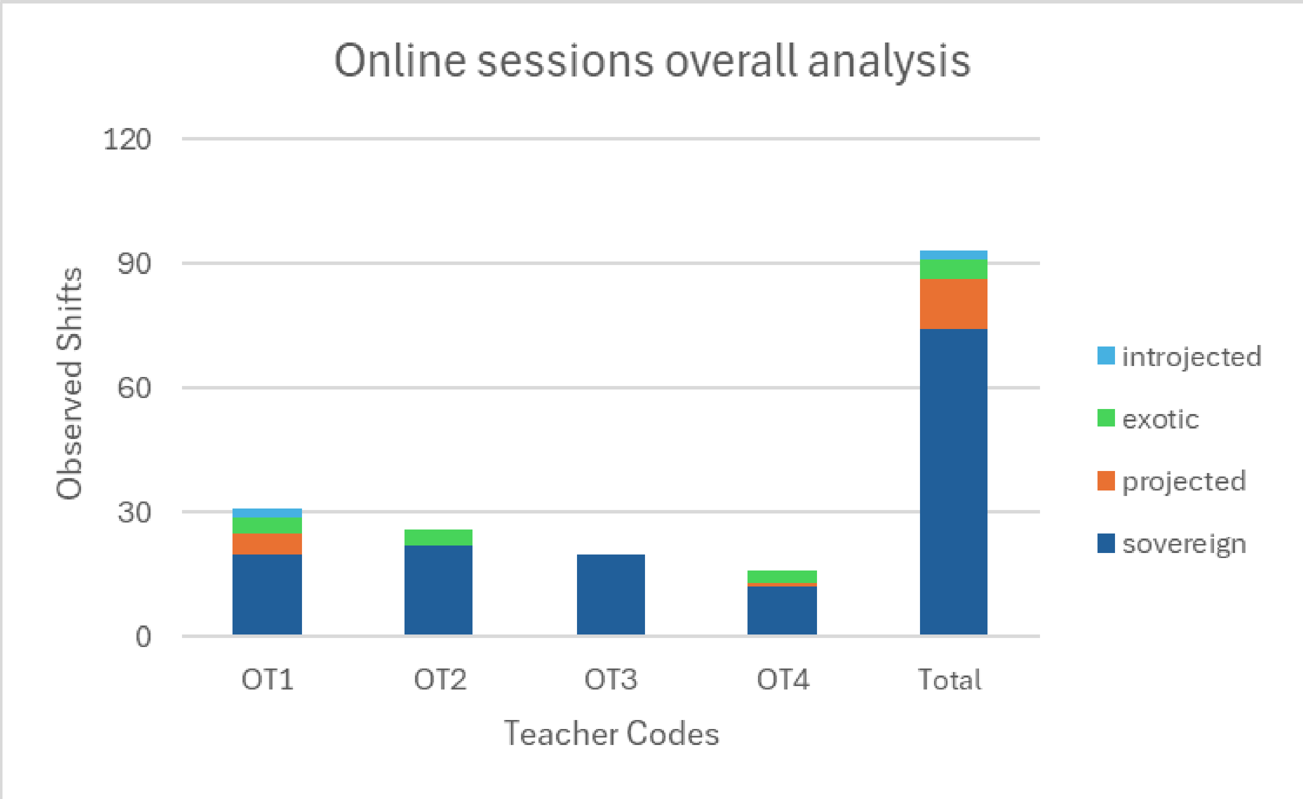


Figure 22: Graph showing overall analysis for online lessons

The graph shows a visual representation of the autonomy shifts made by online teachers in their lessons. Across all the four lessons, the graph indicates that the sovereign code is the most dominant. This shows that the teachers' lessons were centred towards stronger positional and relational autonomy, thereby grounding knowledge within scientific understandings. While this ensures a focus on target content and purposes, integrative knowledge building depends on a teacher’s ability move between multiple autonomy codes over time during instruction. Expanding into other knowledge sources enables learners to master disciplinary concepts while simultaneously connecting that knowledge to other domains.

Looking at the four lessons, OT1 promoted integrative knowledge building effectively. The dynamic movement between the four codes throughout the lesson demonstrates the teachers' ability to successfully venture out in search of other knowledge forms to incorporate into the lesson. What further sets OT1 apart was the ability to repeatedly engage with the same codes, as shown in the autonomy plane (figure 18). This constant shifting and drifting between codes for various purposes fostered integrative knowledge building. OT1 managed to venture out repeatedly to other knowledge sources to enhance to overall learning of the target content. OT4 ranked second since the teacher successfully tapped into three autonomy codes, establishing a complete tour, which is a key indicator for integrative knowledge building. Tapping into the three codes reveals greater opportunities for integrative knowledge building as compared to OT2 and OT3 with fewer or no movements across the codes, resulting in decreased levels of integration.

OT2 was ranked third in terms of integrating knowledge from diverse sources throughout the lesson. This is because the teacher managed to tap into two codes in the entire 30 minutes of the lesson duration. The shifts between the sovereign and exotic codes in this lesson, indicated the teacher's effort to expand knowledge beyond the immediate target concepts. Despite this, the limited number of shifts suggests a more constrained approach to integrative knowledge building than OT1 and OT4. In other words, knowledge remained confined within the technical sciences discipline and the everyday domain. Even so, the shifts to the exotic codes were brief as seen on the autonomy plane (figure 16) thus indicating that most parts of the lesson were grounded in the sovereign codes. Since OT3 remained confined within the sovereign codes, this lesson did not offer any opportunities for integrative knowledge building. While OT1 and OT4 demonstrated successful knowledge integration, the cumulative total reveals that sovereign codes remain dominant across all lessons. This is expected, given that the primary goal of teaching is to develop learners' disciplinary knowledge and skills. However, the analysis suggests a need for OT2 and OT3 to adopt practices that promote integrative knowledge building, such practices are critical to enhance learning experiences and embrace the diversity of knowledge.

5.4. The potential for autonomy pathways observed in contact and online sessions to promote the development of integrative knowledge building

This section focuses on revealing findings relating to the autonomy pathways observed in contact and online sessions. These pathways were further analysed to understand the potential they have in fostering integrative knowledge building in the teaching and learning of organic chemistry. Mapping and capturing the autonomy pathways that teachers opt for is necessary as it explicitly reveals whether integrative knowledge building is successful or not in both contact and online sessions. This section, therefore, seeks to answer the following secondary research question: *How can autonomy pathways in contact and online sessions promote the development of integrative knowledge building?*

In the contact lessons, three types of autonomy pathways were observed: dynamic tours**,** stay pathways**,** and return trips**.** Dynamic tours demonstrated the teacher's ability to shift between three or more autonomy codes repeatedly throughout the lesson. In stay pathways teachers focused solely on one code, typically emphasising target content within sovereign codes. This knowledge was not connected with knowledge from other sources, resulting in the lack of shifts to either the exotic, projected, or introjected codes. Return trips involved shifts between two autonomy codes, with teachers moving between sovereign codes and knowledge from exotic codes. Among the contact teachers, distinct patterns emerged. Contact Teacher 2 (CT2) displayed dynamic tours as the teacher navigated all autonomy codes repeatedly. Contact Teacher 1 (CT1) and Contact Teacher 4 (CT4) exhibited return trips, with shifts between sovereign and projected codes. In contrast, Contact Teacher 3 (CT3) demonstrated a stay pathway, remaining within the sovereign codes for the entire 45-minute lesson without any shifts. While a return trip was observed in CT1, the lesson was mostly characterised by a stay pathway thus establishing two tours in this lesson. The stay being the most dominant pathway and the return trip observed just once in the lesson. The following sections provide a detailed lesson-by-lesson analysis which is accompanied by visual representations to illustrate the autonomy pathways observed across the four contact lessons.

The online lessons on the other hand displayed four distinct autonomy pathways: dynamic tours, complete tours, stay pathways, and return trips most of which are observed in contact sessions. Online Teacher 1 (OT1) demonstrated dynamic tours, repeatedly shifting between all four autonomy codes throughout the 30-minute lesson. This pattern was established through a combination of a return trip and a complete tour across three or more codes. OT1 thus highlighted the ability to navigate multiple autonomy codes repeatedly. Online Teacher 2 (OT2) demonstrated a return trip between the sovereign and exotic codes, where the teacher primarily focused on target content (sovereign codes) while briefly integrating everyday knowledge (exotic codes). On the other hand, OT3 displayed a stay pathway as the teacher remained within the sovereign code for the entire lesson. Lastly, Online Teacher 4 (OT4) presented a complete tour where shifts between three autonomy codes and repeating at least one code was observed. The following sections provide a detailed lesson-by-lesson analysis which is accompanied by visual representations to illustrate the autonomy pathways observed across the four online lessons.

5.4.1. Lesson by lesson analysis of contact sessions

(i) CT1 lesson autonomy pathways

During the 40-minute lesson, which consisted of four episodes of 10 minutes each, the teacher shifted to projected codes only once in episode 2 (based on table 17 in section 5.3.1). This shift was brief and occurred solely to link mathematical knowledge to the core content, as illustrated on the autonomy plane in Figure 12. Following this shift the teacher quickly established a way back to the sovereign codes in which the focus was on knowledge or ideas emanating from technical sciences as prescribed through the curriculum. This entails that CT1 predominantly spent a significant amount of time on target content and purposes thereby staying within the sovereign codes for most parts of the lesson. Figure 23 below illustrates a stay pathway which explains knowledge that reside within the same code.

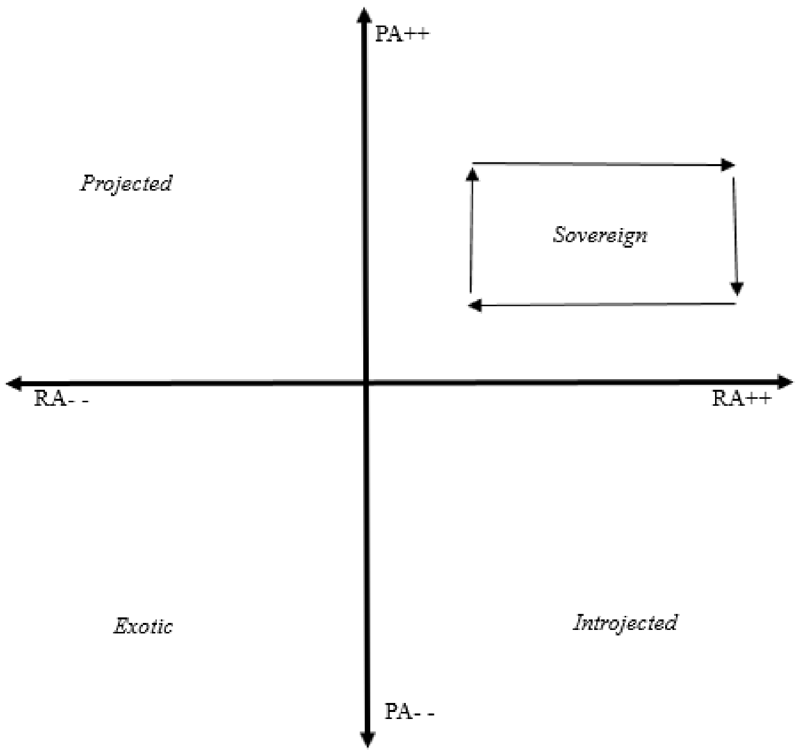


Figure 23: Stay pathway

While most parts of the lesson focused on ideas from technical sciences aimed at deepening and enhancing understanding of organic chemistry (sovereign code), the teacher shifted to the projected code once during the lesson as previously mentioned. Doing so established a brief return trip between the sovereign and projected codes as seen in the figure below. At this point, the teacher weakened relational autonomy (RA-) by focusing on procedures that emanate from other domains (i.e. mathematics). However, positional autonomy remained stronger, as the focus stayed within the boundaries of the discipline.

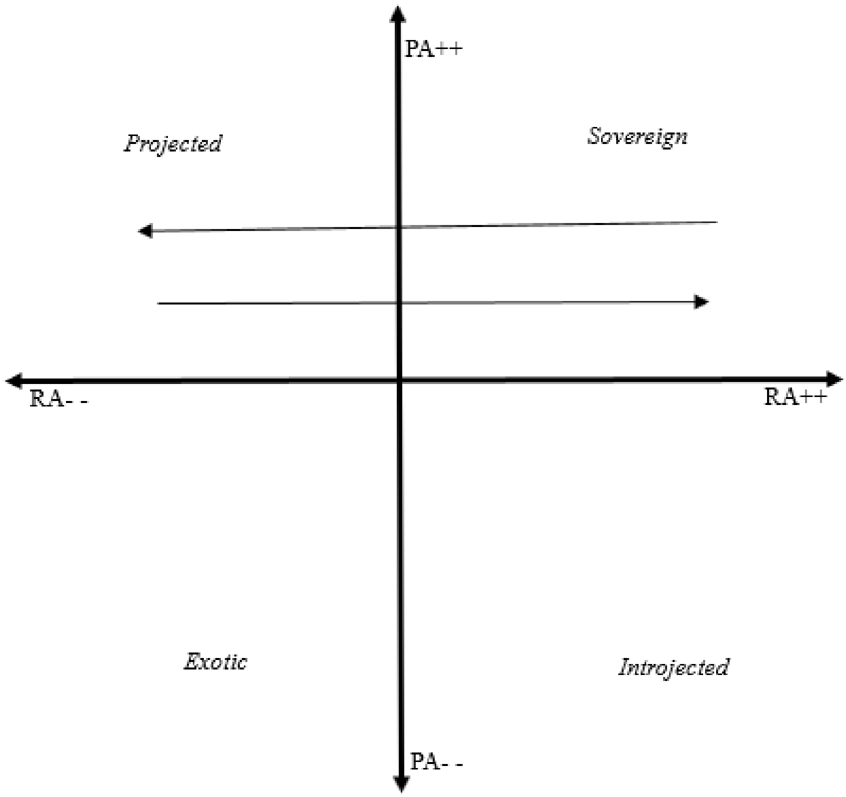


Figure 24: A return trip

Considering that the shift to the projected codes was brief and less successive, the lesson was mostly characterised by stay pathways, which present limited potential for integrative knowledge building. In the post-lesson interview, the teacher explained how he could have extended his lesson to the exotic codes by using everyday visual representations accompanied by everyday explanations. The teacher gave the response that followed when asked what he would change if he had to teach the same lesson again:

TEACHER: *I will use, I don't know, like a chain. You see how a chain is structured—an every-day chain? How then can it be extended without changing the structure of it? It's something that I can use. I am also thinking of a rope; if I fold it once, it means it's a bond, and if I fold it twice, it becomes a double bond. But it changes, because if I fold it twice, it's going to be stronger, whereas in organic chemistry, it's going to be weak. So that's where it's going to be a challenge.*
I don't know; maybe my example won't be fit enough, because when you talk about saturated, they are stronger than unsaturated, and then now we are talking about a double bond, so it's kind of a fold. So, this fold must, according to them (learners), be stronger, whereas in this case it is weaker.

In the above extract, the teacher was highlighting aspects that could be done to enable the lesson to shift at least between the sovereign, projected, and exotic codes. Interestingly, the teacher highlighted potential misconceptions that could arise when the exotic codes are brought into the equation. Perhaps this explains why in the lesson such practices were not touched on!

(ii) CT2 lesson autonomy pathways

CT2 teacher managed to switch between all four codes in the overall lesson. There was series of strengthening and weakening of both positional autonomy and relational autonomy as the lesson progressed. The clusters on the plane in figure 13 also reveal the number of times the teacher tapped into each code in the overall lesson. The repeated shifts between three or more codes represent an autonomy tour in which learning can start in one code, progress through several codes, and then return to where it started. As mentioned previously, there is an unlimited number of potential movements across the plane. The CT2 lesson portrays two different kinds of complete tours that begin from different codes, as seen in figures 25 and 26 below.

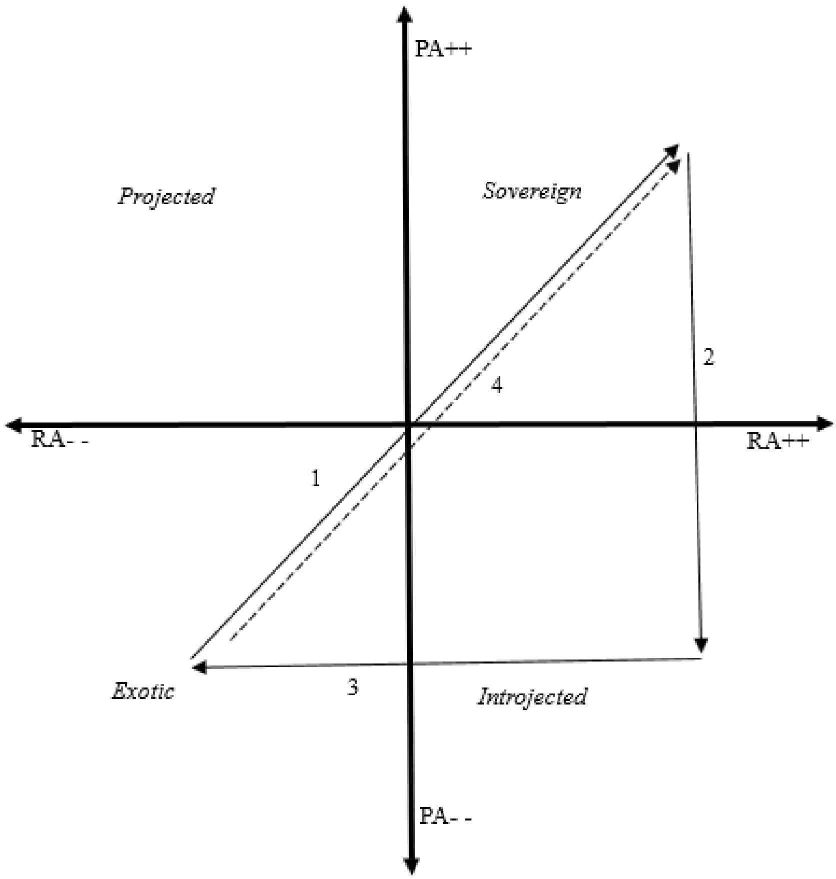


Figure 25: CT2 first autonomy tour

Figure 25 above shows a complete autonomy tour that begins from the exotic codes to the sovereign codes, then the introjected codes, and back to the exotic codes. Compared to CT1, the teacher could incorporate everyday knowledge into the lesson; however, knowledge is not left at everyday understanding; the teacher then returns to the sovereign codes (shown by a dotted line). From the sovereign codes, the teacher was able to shift again to the introjected codes, then projected codes, and then made a return to the sovereign codes as shown in figure 26 below.

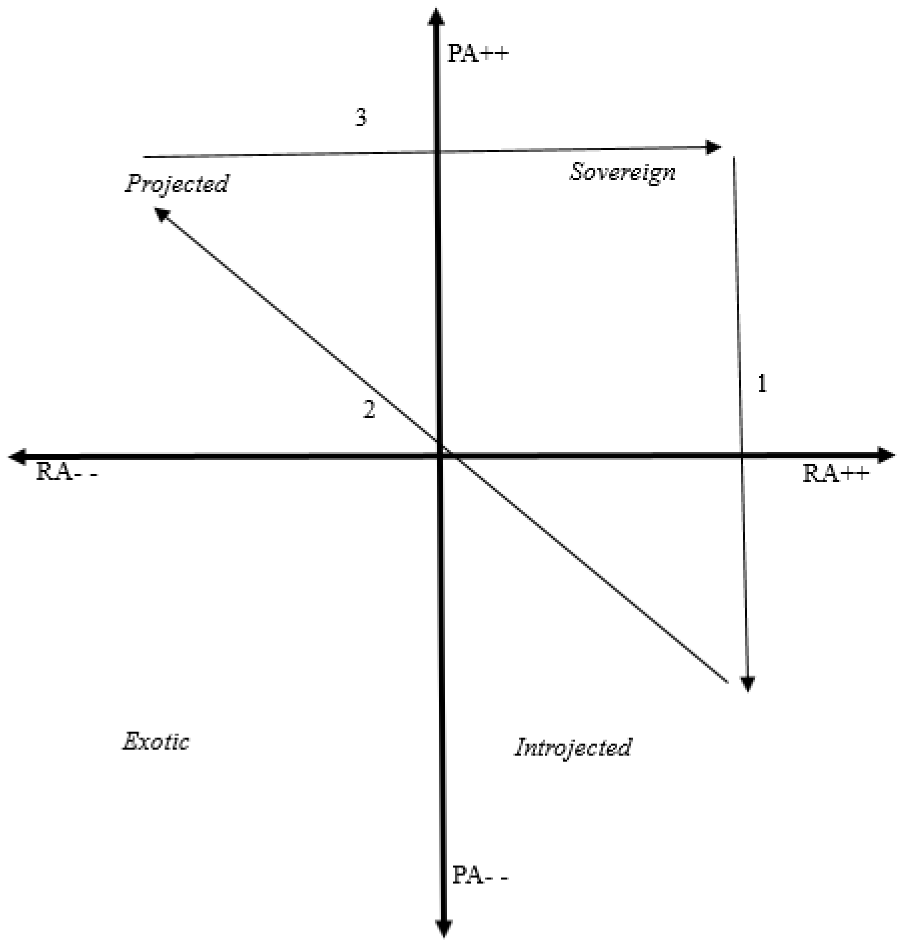


Figure 26: CT2 second autonomy tour

As complex as teaching is, teachers ought to be able to integrate knowledge from different sources during instruction. CT2 portrays this integration well as the lesson repeatedly shifts between all four codes in the overall lesson. To clearly highlight the successful integration of knowledge as portrayed in this lesson, figure 27 below depicts tours mapped in the entire lesson, which is a combination of figures 25 and 26. The labels and pathways in figure 27 reflect dynamic movements through numerous codes, demonstrating greater opportunities for integrative knowledge building.

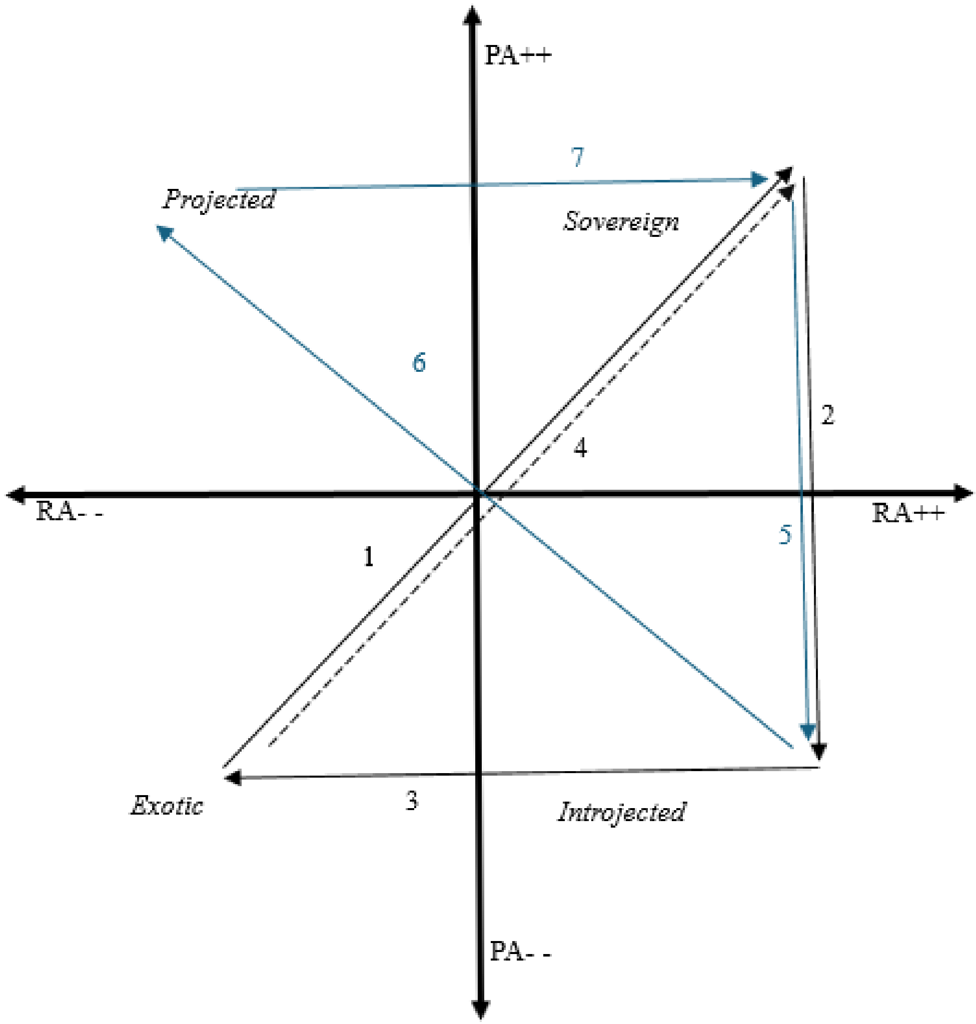


Figure 27: Combined autonomy tour

(iii) CT3 lesson autonomy pathways

The pathways from the CT3 lesson are described as a stay pathway in which knowledge practices reside in a single code (as illustrated in figure 28 below). In the case of this lesson, similar to CT1, the teacher stayed within the sovereign codes. This entailed overly focusing on the target content and purposes which explain knowledge emanating from the topic of organic chemistry and related topics from the technical sciences curriculum. According to the context of this lesson, this knowledge was introduced for the purposes of deepening and consolidating understanding of the targets. Staying in the sovereign code highlights the teachers' intention to build a solid foundation of the target content, but it also reveals a limitation in tapping into other knowledge sources to broaden the scope of knowledge gained by learners. As previously mentioned, stay pathways constrain the potential for integrative knowledge building. An emphasis on the mastery of the target content aligns the lesson towards the expectations of the discipline, which is key in any learning situation. CT3 lesson, however, limits learners' exposure to other knowledge forms, such as every day or knowledge from other domains. Successful integration of knowledge requires teachers to move beyond a single code to engage with multiple knowledge forms. The absence of such shifts reduces opportunities for learners to develop a more holistic understanding of the target content.

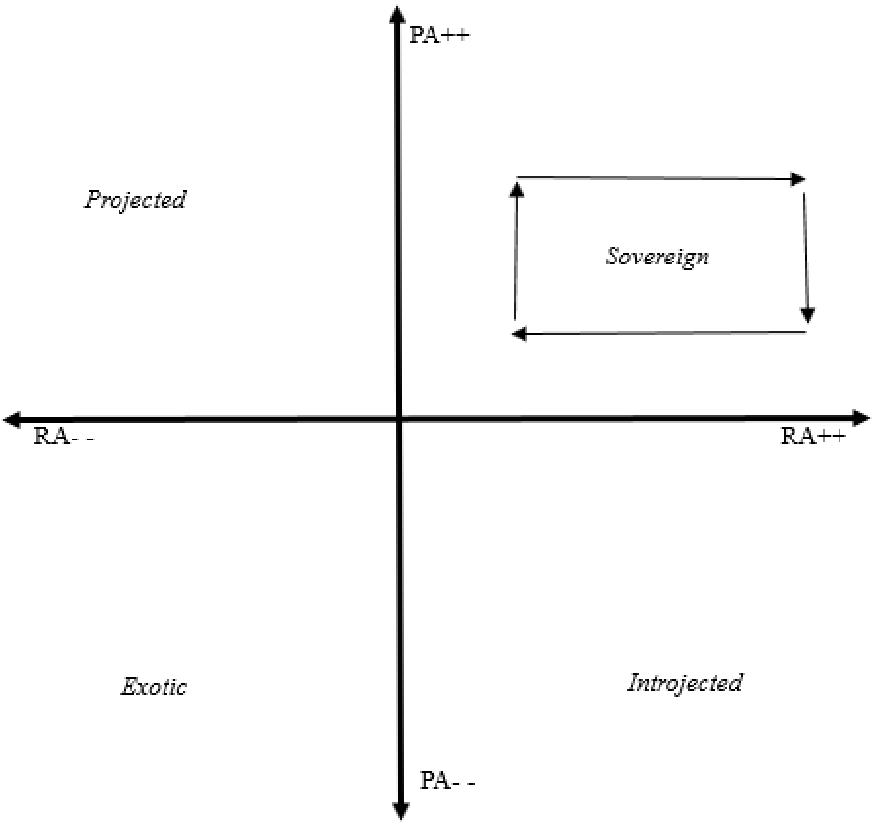


Figure 28: Stay pathway

(iv) CT4 lesson autonomy pathways

The pathways identified in CT4 lesson reflects a return trip, which in the case of this lesson is explained by shifts from sovereign codes to projected codes, then back to sovereign codes overtime in the lesson. The observed autonomy pathway between sovereign and projected codes reveals the simplest form of a tour with integration of teaching procedures from different sources (e.g., mathematics procedures and organic chemistry procedures). While the interplay between the sovereign and projected codes ensures mastery of target content, the absence of shifts into other codes limits opportunities for integrative knowledge building. For instance, the CT4 lesson remains narrowly focused on target content without integrating knowledge from learners' daily contexts (everyday knowledge) or other disciplines, which may enhance learners' understanding of the overall content. This kind of pathway may result in learners viewing knowledge as isolated, thus impeding the transfer of concepts across disciplines and applying knowledge to real-life contexts. While the pathways that CT4 opted for build conceptual depth, exploring exotic and introjected codes could help foster integrative knowledge building.

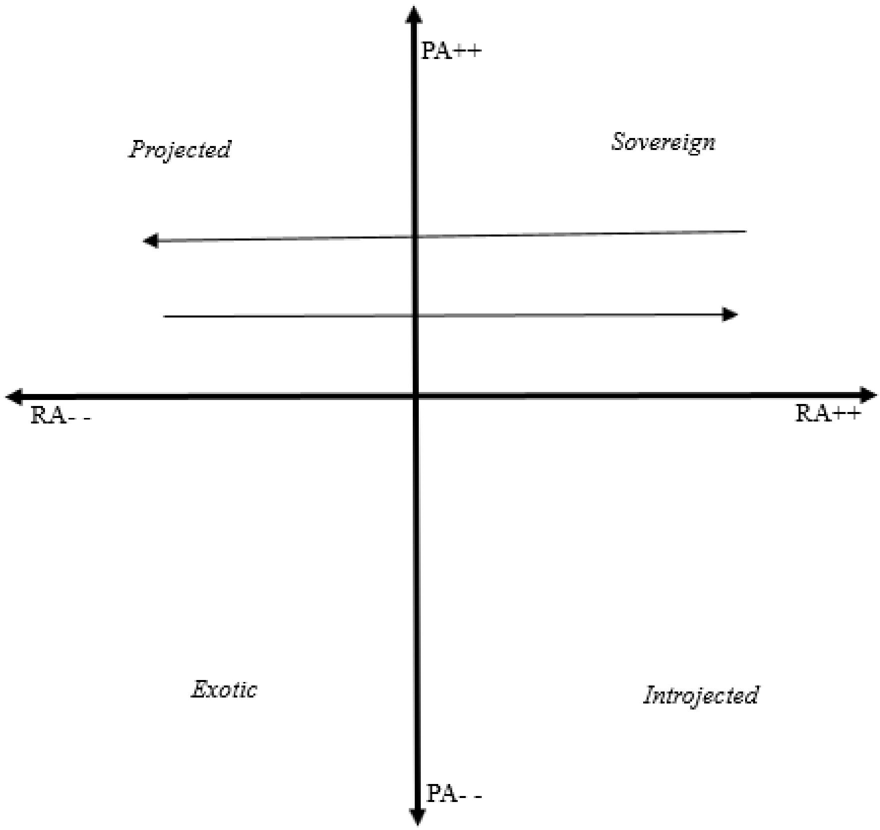


Figure 29: CT4 lesson autonomy pathway (a return trip)

5.4.2. Lesson by lesson analysis of online sessions

(i) OT1 lesson autonomy pathways

OT1 lesson is characterised by pathways that indicates shifts between all the autonomy codes overtime in the lesson. As illustrated in the autonomy plane below, the teacher weakened and strengthened positional autonomy and relational autonomy over time in the lesson. The degree of strengths in these codes is dynamic such that movements between a single code happens multiple times (highlighted in the autonomy plane in figure 18). The ability of the teacher to repeatedly tap into all the four autonomy codes establishes a complete tour which is described as a movement between three or more codes. The shifts observed in this lesson resulted into two different autonomy pathways that begin from different codes. The first pathway is a complete tour that begins from the exotic codes all the way through the sovereign, introjected and back to the sovereign codes as illustrated below.

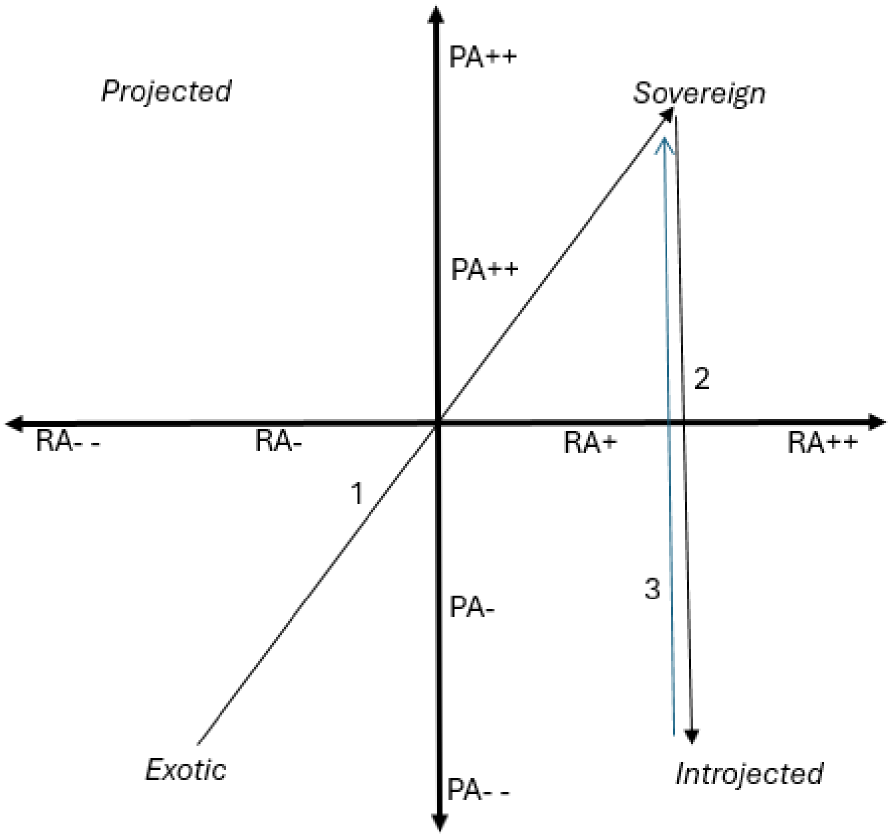


Figure 30: A complete tour

The second autonomy pathway is a return trip between the sovereign and projected codes as illustrated below.

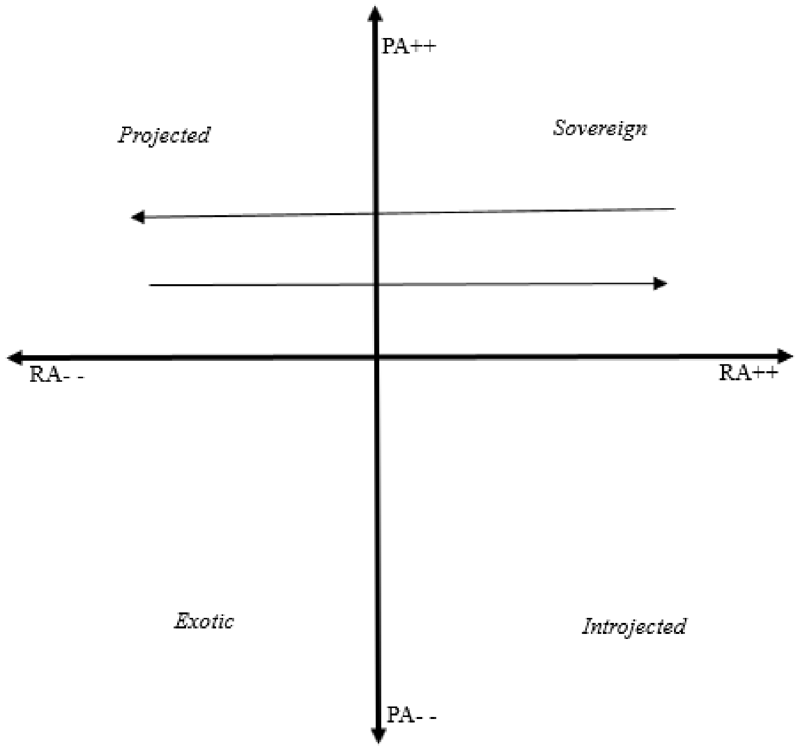


Figure 31: A return trip between the sovereign and exotic codes

The key point from the above pathways (Figure 30 and 31) is that one way or another the teacher managed to make a trip back to the sovereign codes. To clearly visualise the dynamic nature of the shifts observed in this lesson, a combined tour as illustrated in figure 32 below was necessary.

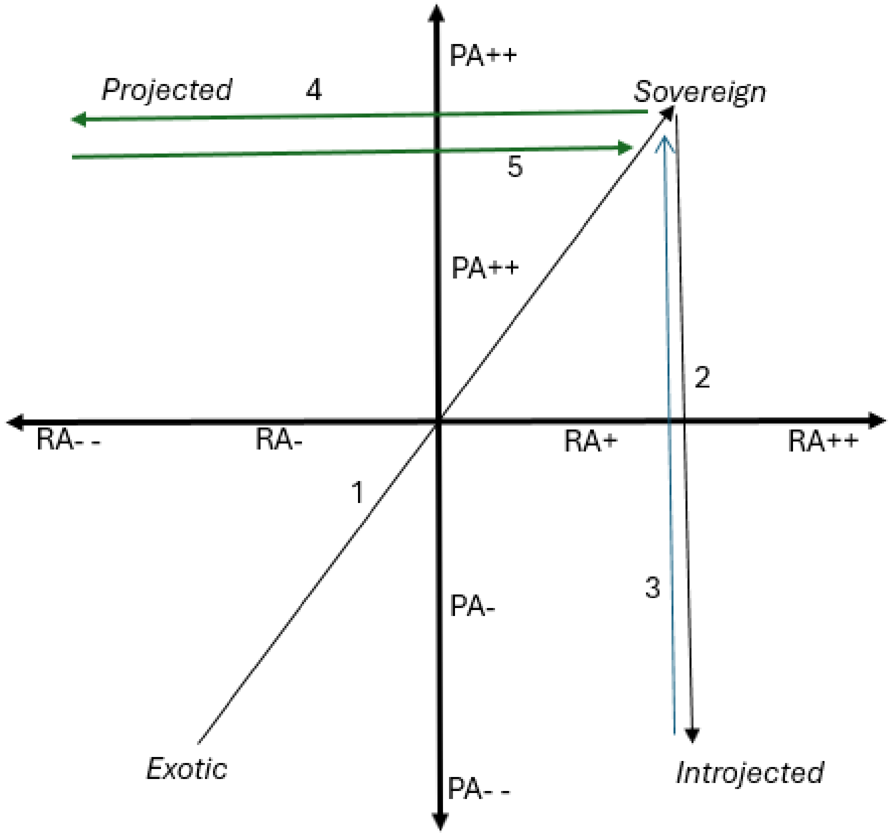


Figure 32: Combined autonomy tour (dynamic tour)

(ii) OT2 lesson autonomy pathways

The autonomy pathway illustrated in OT2 lesson is categorised by a return trip between the exotic codes and the sovereign code over the course of the lesson. Initially, the teacher departed from the scientific domain (sovereign codes) to incorporate knowledge forms that are less directly related to the target content (exotic codes). This approach indicates teaching processes that integrates knowledge from other domains thus reflecting interdisciplinary and contextual learning opportunities. However, a key observation is that the teacher later returned to the sovereign code, indicating the link between non-target content and purposes with targets.

A return trip represents a simple tour, demonstrating the teacher's ability to venture beyond the discipline in search of relevant knowledge that enhances learners' understanding of key concepts. In this lesson, while the shift to exotic codes was necessary, it was too brief to facilitate meaningful integrative knowledge building. This contrasts with pathways observed in OT1, where shifts were more dynamic and intentional. Notably, the transition to exotic codes occurred within the first 10 minutes of the lesson, whereas the remaining 20 minutes were confined to the sovereign code. As a result, the teacher's approach in this lesson provided limited opportunities for effective integrative knowledge building.

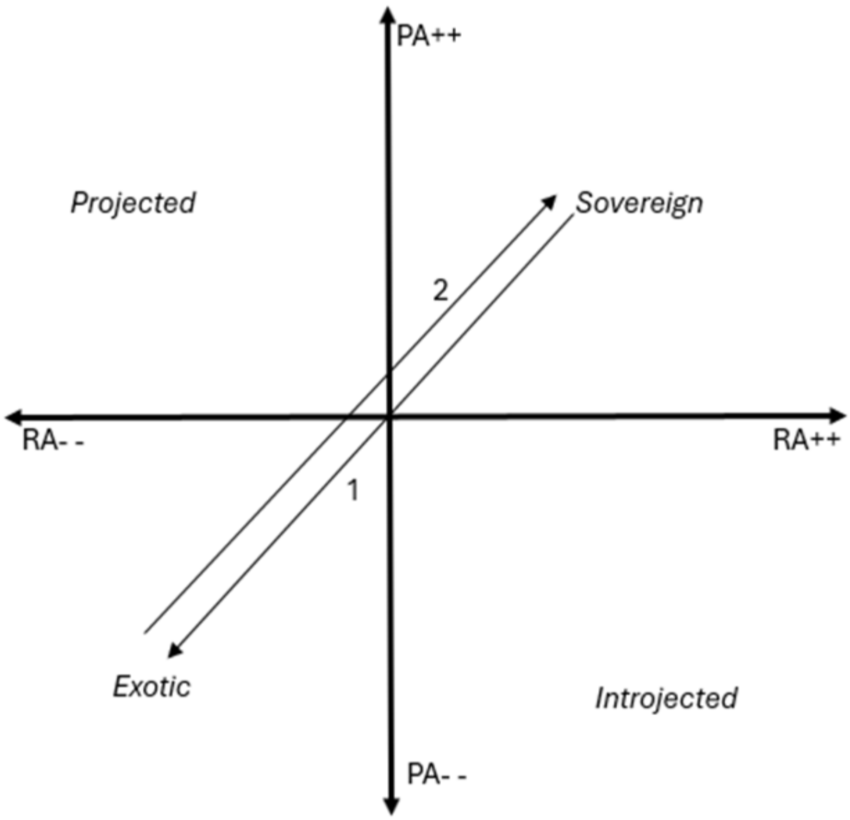


Figure 33: A return trip between the exotic and sovereign codes

(iii) OT3 lesson autonomy pathways

Considering that OT3 resided within a single code throughout the lesson, stay pathways were evident in this lesson. By staying within the sovereign code, the teacher did not draw on diverse sources to develop a holistic understanding of the target content. In the case of this lesson disciplinary concepts are not linked to any other knowledge forms thus integrative knowledge building is constrained. As a result, learning becomes segmented, making it difficult for learners to relate scientific concepts to their prior knowledge, experiences, or procedures from other disciplines. In other words, learners may struggle to see connections between the target concepts and what they have or are learning in different subjects or contexts. This in turn hinders the ability for learners to adapt knowledge beyond instruction.

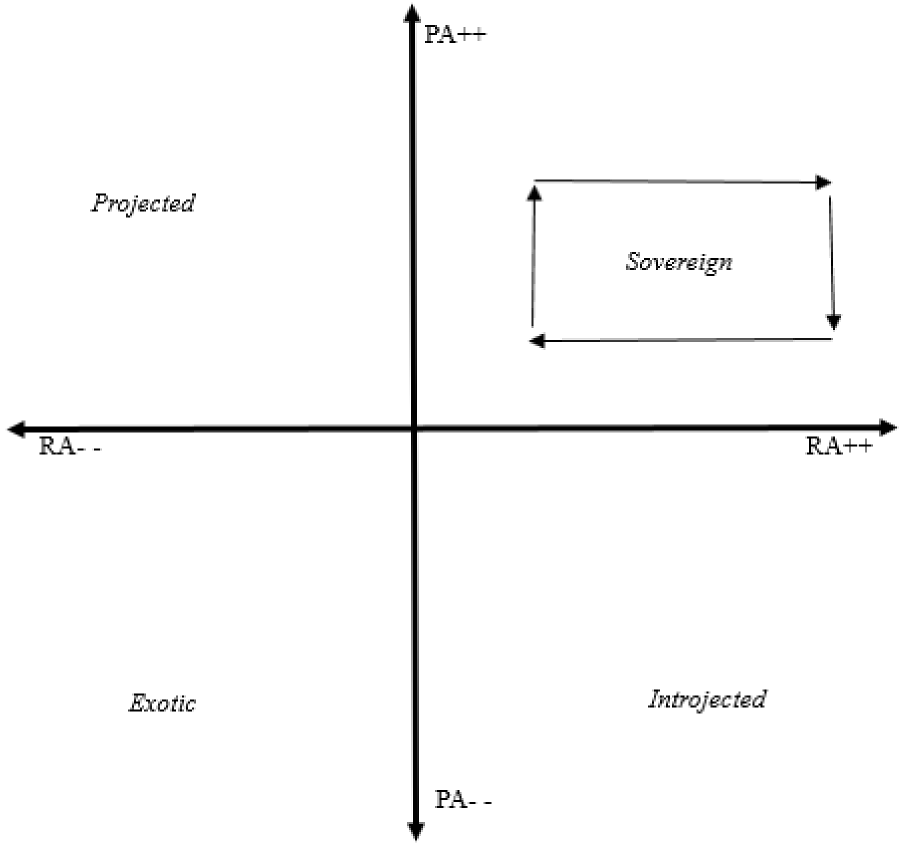


Figure 34: Stay pathway in OT3 lesson

(iv) OT4 lesson autonomy pathways

OT4 lesson was characterised by a complete tour as seen in figure 35 below. A complete tour is described by the movement across three or more codes. In this lesson, the teacher transitioned from exotic codes to sovereign codes via projected codes, then briefly returned to exotic codes before concluding within the sovereign codes. The autonomy pathways established in this lesson demonstrate great potential for integrative knowledge building. By strategically venturing out to other knowledge sources, the teacher facilitates a holistic understanding of key concepts. This practice ensures that learners not only comprehend the target concepts but also appreciate its broader relevance and applicability.

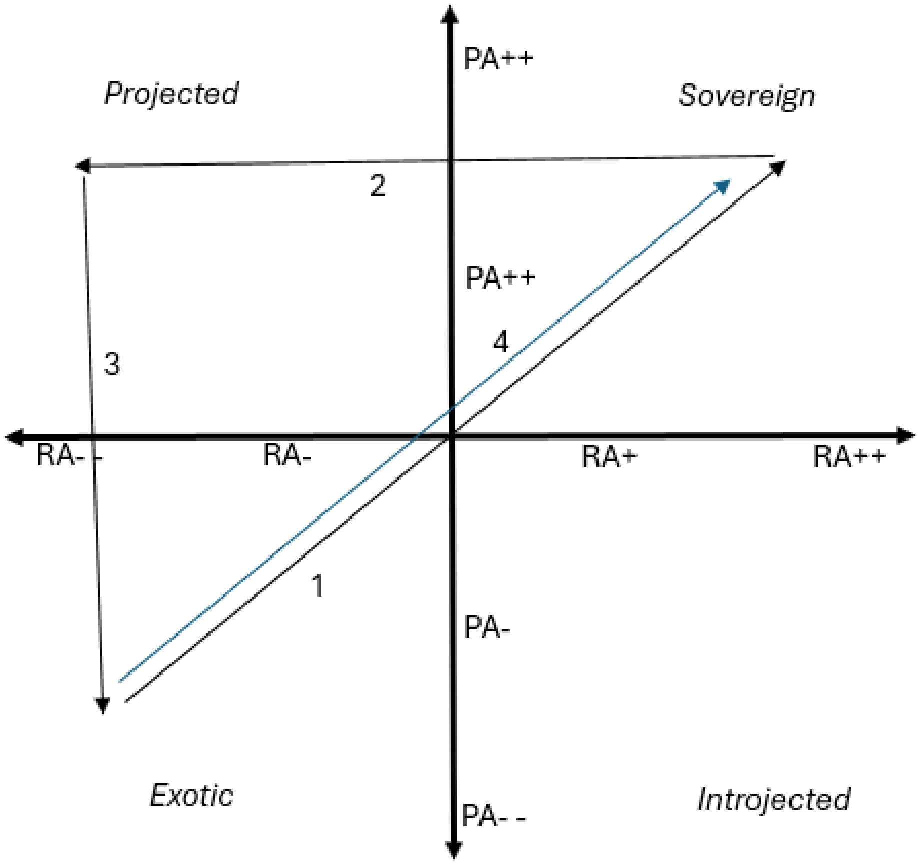


Figure 35: Complete tour

5.4.3. The potential for integrative knowledge building in contact and online sessions based on the similarities and differences in the pathways

All the lessons observed are ranked from highest to lowest in terms of the potential for teachers to build knowledge that is integrative in their lessons. Table 32 below illustrates the rankings based on the pathways observed and other factors such as the characteristics of the lessons.

Table 32: Demonstrates the ranking of all lessons for their potential for integrative knowledge building based on the autonomy pathways observed

Rank	Lesson (Code)	Pathway Type	PA/RA Characteristics	Potential for Knowledge Building	Modality
1st	CT2	Dynamic Tour	7+ shifts between weaker PA and RA and stronger PA	Highest	Contact
2nd	OT1	Dynamic Tour	5 shifts across 4 codes, between weaker PA and RA and stronger PA and RA	High	Online
3rd	OT4	Complete Tour	(4 shifts, no introjected codes) between weaker PA and RA and stronger PA and RA	Moderate to High	Online
4th	OT2	Return Trip	Stronger PA and RA with Weaker PA and RA (Sovereign ↔ Exotic)	Moderate	Online
5th	CT4	Return Trip	Stronger PA and Weaker RA (Sovereign ↔ Projected)	Moderate	Contact
6th	CT1	Stay + Return Trip	Stronger PA and RA infused with weaker RA (One shift to the projected, mostly stay)	Moderate to Low	Contact
7th	CT3	Stay Pathway	Stronger PA, Stronger RA (Sovereign only)	Low	Contact
7th	OT3	Stay Pathway	Stronger PA, Stronger RA (Sovereign only)	Low	Online

As previously outlined a variety of autonomy pathways were identified across contact and online lessons. Based on the table above, dynamic tours, as seen in CT2 and OT1, demonstrated the highest potential for integrative knowledge building. CT2 lesson was ranked first since the teacher managed to tap into diverse knowledge sources through seven successive shifts across autonomy codes. OT1 on the other hand was ranked second since the teacher established integration of knowledge through five successive shifts across all four autonomy codes which were slightly fewer than CT2 lesson. Furthermore, moderate knowledge-building potential was observed in lessons with complete tours and return trips. For instance, OT4, which ranked third, demonstrated a complete tour with four shifts across the autonomy codes.

OT2 was ranked fourth as moderate potential for knowledge building was noted as the teacher links knowledge through the sovereign and the exotic codes. Even though CT4 presented a return trip between the sovereign and projected codes, the lesson was ranked number five also presenting moderate integrative knowledge building. The lowest potential for knowledge building was evident in lessons that were characterised by stay pathways, such as CT3 and

OT3. These lessons were both ranked number seven in terms of their potential to build knowledge that is integrative. As previously mentioned, these lessons maintained strong PA and RA, restricting knowledge to sovereign codes without integrating knowledge from diverse sources. CT1 lesson on the other hand was ranked number six as the lesson revealed a slightly higher potential for integrative knowledge than CT3 and OT3 due to a single return trip to projected codes, despite being characterised primarily by a stay pathway.

An overall analysis reveals that online lessons demonstrated a greater potential for integrative knowledge building as compared to contact lessons. Among the top four ranked lessons, three were online (OT1, OT4, and OT2), while only one contact lesson (CT2) demonstrated greater potential for knowledge integration. OT1 lesson, which ranked second overall, managed to tap into all four autonomy codes, demonstrating dynamic tours with multiple shifts between weaker and stronger positional autonomy (PA) and relational autonomy (RA). Similarly, OT4 lesson which ranked third demonstrated a complete tour with four successive shifts. Furthermore, OT2 was ranked fourth as it presented a rerun trip between the sovereign and exotic codes thus provide moderate potential for integrative knowledge building. In contrast, most lessons in contact sessions revealed limited opportunities for integrative knowledge building with CT2 being the exception. For example, CT1 and CT4 lesson were characterised by moderate integration while CT3 was ranked lowest alongside OT3 reflecting minimal integration of knowledge from other sources. In general, the analysis highlights that while contact lessons, particularly CT2, can achieve greater integrative knowledge building potential through dynamic tours, online lessons consistently offer broader opportunities for knowledge integration across multiple autonomy codes.

It is, however, important to note that these rankings are not presented as absolute or prescriptive. The degree of integrative knowledge building cannot be reduced solely to the number of observed autonomy shifts, as these movements are shaped by several interrelated factors including the lesson topic, the disciplinary nature of science, teacher intentions, and contextual dynamics such as learner engagement or preferred teaching strategies. In this study, the ranking reflects a relative measure of potential within the observed lessons rather than an inherent hierarchy of effectiveness. Different studies, disciplines, or instructional designs may yield different patterns and interpretations, depending on how autonomy pathways are operationalised and judged by the researcher in relation to the phenomenon under scrutiny. Thus, the rankings should be viewed as a context-bound representation of how integrative knowledge building manifested in these particular lessons rather than a universal measure of instructional quality.

Although the autonomy pathways provide insights into the potential for integrative knowledge building within the lessons, they do not reveal the specific knowledge practices that informed the observed pathways. Understanding these practices offers insights into revealing factors that enable or constrains integrative knowledge building in these two distinct modes. Such an understanding is necessary for developing a framework that leverages the strengths of each mode, ultimately revealing integrative knowledge-building practices in blended learning contexts. As stated in Chapter 1, the primary aim of this study is to explore how integrative knowledge building takes place in both contact and online contexts to inform pedagogy within blended learning contexts. The goal is to contribute to the development of a blended instruction integration model that places knowledge practices at its core. As previously mentioned, this study addresses the problem of existing blended instruction models, which often lack an understanding of practices that reveal how teachers work with knowledge in blended contexts.

5.4.4. Summary of observations made from contact and online sessions.

In both contact and online sessions, stay pathways, return trips, and tours were observed. Stay pathways were noted in CT1, CT3, and OT3, where teachers remained within the sovereign codes. This indicates a strong focus on content and purposes as prescribed through the technical sciences curriculum. Overly focusing on the targets limited opportunities for integrative knowledge building, as the teachers failed to tap into other knowledge sources such as exotic, projected, or introjected codes. In these lessons, the teachers focused on consolidating and deepen understanding of the topic of organic chemistry. Even though this was the target purposes, limiting understanding within the sovereign codes has severe implications for integrative knowledge building. In addition, although a stay pathway was observed in CT1, the lesson included a brief return trip. This positioned CT1 better in terms of the potential for integrative knowledge building as compared to CT3 and OT3, which remained strictly within the sovereign codes without any shifts to other knowledge sources.

Return trips were observed in CT4, CT1, and OT2 as the teachers managed to shift between two autonomy codes. However, a few distinctions were noted between these two modalities. In contact lessons, return trips extended knowledge to the projected codes, linking the content to mathematical knowledge (CT1) or assessment purposes (CT4). In contrast, OT2 extended knowledge to the exotic codes through linking target concepts with learners' everyday knowledge or experiences. Despite the variations in the purposes of the enactment of these codes, all three return trips remained limited to two codes thereby constraining the potential for integrative knowledge building in these lessons. Even though the teachers managed to shift into other codes in search of knowledge or skills relevant for learners to understand the targets, it remained notable that the sovereign codes were dominant.

This indicates that the shifts to other codes were too brief. For instance, CT1 included a single shift to the projected code, CT4 involved three shifts to the projected code, and OT2 presented four shifts to the exotic code. The ability of OT2 to shift to the exotic codes in which both positional and relational autonomy were weakened for that period marked a link between disciplinary knowledge with everyday understanding. Thus, OT2 presented a more integrated approach to learning as compared to CT1 and CT4. shifts to the projected codes in CT1 and CT4 only weakened relational autonomy, as the focus remained on procedural knowledge (e.g., mathematical linking or assessment purposes) as previously mentioned. This means that while all three lessons featured return trips, OT2 presented better opportunities for integrative knowledge building by broadening knowledge beyond disciplinary boundaries. This difference positions OT2 above CT1 and CT4 in terms of enabling integrative knowledge building during instruction.

Autonomy tours were observed in CT2, OT1, and OT4 as teachers managed to shift between three or more autonomy codes. However, a few differences were noted in the patterns and frequency of shifts resulting to these pathways. CT2 demonstrated tours which I consider dynamic as the teacher managed to establish seven successive shifts between all four autonomy codes. Doing so reflected an expanded level of repeatedly engaging with diverse knowledge sources. Even though a dynamic tour was noted in OT1, the teacher managed to successfully establish five successive shifts. OT4 on the other hand exhibited a complete tour with four successive shifts which did not include the introjected codes. Given that CT2 demonstrated the most diverse and repeated shifts across all the four autonomy codes it is ranked the highest in terms of the potential for integrative knowledge building followed by OT1 and OT4. In all these lessons, teachers actively sought knowledge from various sources, demonstrating a deliberate effort to integrate diverse knowledge forms to support learners' understanding of the target concepts.

5.5. Knowledge practices in blended learning environments that can promote integrative knowledge building effectively

The main aim of this section is to present findings that reveal the knowledge practices essential for teachers to build integrative knowledge in blended learning contexts. This study analysed contact and online sessions separately to develop a robust understanding of knowledge practices within each mode. This kind of understanding is essential because it clearly reveal the practices that promote or hinder integrative knowledge in both contact and online contexts. The section aims to uncover practices that foster integrative knowledge building in blended learning contexts through identifying the strengths of each mode. Bended instruction in the context of this study refers to face-to-face teaching and learning processes infused with instruction delivered via asynchronous online learning. In asynchronous learning, teachers pre-recorded videos that learners would engage with at their own convenience.

In the preceding section, the study revealed autonomy pathways in each mode and ranked the lessons based on their potential for integrative knowledge building. The autonomy pathways provided insight into whether knowledge building occurred or not in these lessons through tracing the paths or trajectories that teachers followed in their lessons. Although the autonomy pathways were successful for understanding the potential for integrative knowledge building in lessons taught in both modalities, they did not explicitly reveal the knowledge practices embedded within these contexts. Therefore, this chapter shifts focus to uncovering the knowledge practices that informed the autonomy pathways observed in these lessons.

This chapter reveals findings answering the following secondary research question: What practices in blended learning environments can foster integrative knowledge building effectively? To address the question, the session is organised as follows:

i. An analysis of knowledge practices in contact sessions: In this section an analysis of the knowledge practices observed in the four analysed contact lessons will be done. Doing so will facilitate in highlighting practices that enabled or constrained integrative knowledge building in this context.
ii. An analysis of knowledge practices in online sessions**:** This section aims to uncover knowledge practices inherent in online sessions, thereby discussing their contribution to or limitation of integrative knowledge building.
iii. A comparative analysis of knowledge practices across contact and online modes**:** At this point, similarities and differences in knowledge practices observed in contact and

online sessions will be revealed. Additionally, the section will highlight practices that are unique to each mode or shared across both modes.

iv. Essential knowledge practices for integrative knowledge building in blended instruction: In this section, a synthesis of key knowledge practices that enable integrative knowledge building across both contact and online contexts will be discussed. This section will also highlight the pedagogical significance of these practices for blended instruction.

This section is an important part of the study simply because it goes beyond the autonomy pathways previously presented to highlight the specific knowledge practices that promote integrative knowledge building in blended learning settings. The findings presented in this section directly contribute to developing a blended learning pedagogical integration model that foregrounds how teachers work with knowledge or knowledge practices that teachers opt for to support meaningful integrative knowledge building learning experiences for their learners in science education.

5.5.1. Key knowledge practices in contact sessions

As previously mentioned in contact sessions four types of autonomy pathways namely, stay pathways, return trips, complete tours and dynamic tours were observed. These pathways were identified as either enabling or constraining integrative knowledge factors in these lessons. For instance, the successful integration of knowledge forms in the CT2 lessons was noted by dynamic shifts between codes, mapped as dynamic autonomy tours. In contrast, the CT3 lesson constrained integrative knowledge building through opting for stay pathways, indicating staying within the same autonomy code throughout the lessons. While CT1 and CT4 presented opportunities for integrative knowledge building, these were limited in scope, as observed through the return trips. As stated before, the autonomy pathways provide a visual representation of processes that take place overtime in the lesson but do not directly give an indication of the kind of practices that either enable or constrain integrative knowledge. Thus, observing the pathways that teachers opted for and analysing specific dynamics such as the role of learners or the teachers and the conditions for the enactment of the codes allows for a comprehensive understanding of knowledge practices that emerged in these lessons.

Pulling these observations together makes visible the forms of knowledge practices that foster integrative knowledge building in contact sessions as a constituent of blended instruction. As highlighted in Chapter 1, the problem that this study is addressing is the lack of visibility or recognition of knowledge practices that are embedded within blended learning contexts. Figure 36 below provides a visual representation of knowledge practices that emerged from contact sessions, categorising them as either enabling or constraining factors for integrative knowledge building (IKB).

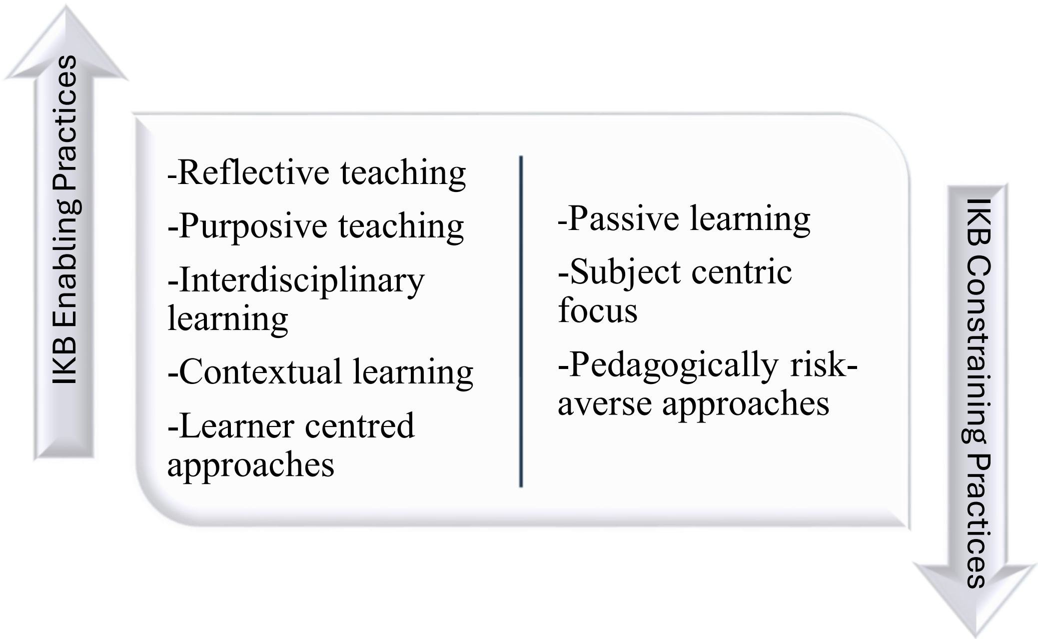


Figure 36: Integrative knowledge-building (IKB) practices identified in contact sessions

As shown in the figure 36 above, five knowledge practices emerged as integrative knowledge building enabling practices, whereas four practices were identified as knowledge building constraining practices. The sections that follow provide extensive details relating to this classification guided by theory and contextual conditions. The knowledge practices outlined in this section are classified according to the autonomy pathways observed in the analysed lessons. These autonomy pathways reflect the ways in which teachers moved between different strengths of positional autonomy (PA) and relational autonomy (RA) during instruction, as represented on the autonomy planes. Lessons that demonstrated dynamic movement between target and non-target forms of understanding were associated with greater potential for integrative knowledge building, as such movement reflects the capacity to connect specialised disciplinary knowledge with other relevant forms of knowledge or contexts.

The number and quality of these shifts were central to the classification. Lessons characterised by multiple and meaningful shifts across autonomy codes, where teachers facilitated movement between distinct knowledge contexts and relational networks, were deemed to exhibit enabling knowledge practices. In contrast, lessons that showed limited or static pathways, where movement across autonomy codes was minimal or absent, were associated with constraining practices that limited opportunities for integrative knowledge building. Thus, the distinction between enabling and constraining practices rests on the observed degree of autonomy shifts and the extent to which these shifts supported knowledge integration over time.

Additional insights were drawn from the contextual and pedagogical dynamics that shaped the observed autonomy pathways. For instance, in cases where teachers engaged in reflection-in-action and deliberately weakened or strengthened positional (PA) or relational autonomy (RA) to consolidate or deepen understanding in response to learners' needs, corresponding shifts in autonomy codes were observed. Such adaptive pedagogical actions reflected the teachers' responsiveness to emerging learning needs and illustrated how real-time instructional decisions can promote integrative knowledge building during teaching.

5.5.1.1. IKB enabling practices in contact sessions

(i) Reflective teaching practices

Reflective teaching practices emerged as a key factor enabling integrative knowledge building in contact sessions. Observations revealed that teachers were able to reflect in action, adapting their pedagogical strategies based on learners' responses to the content. Reflective shifts were evident when learners displayed confusion through facial expressions, verbal cues, or a lack of response to posed questions. The teachers would strengthen or weaken positional autonomy (PA) or relational autonomy (RA), depending on the learners' needs. Tools such as facial expression or verbal cues played a huge role in helping the teacher to identify if learners grasped the concepts or not leading to the issues being addressed instantly. This highlights the benefits of contact sessions where such cues would be missed in other settings, such as asynchronous online learning.

CT1 and CT2 were able to alter their explanations or examples by weakening or strengthening PA or RA to enable learners to grasp the target concepts. Additionally, the teachers' abilities to bring in diverse knowledge forms as a means of supporting understanding avoid the issues of essentialism, which regards knowledge practices as unchanging (Maton and Howard, 2018). The reflective practices highlight the relationship between pedagogy and the content, illustrating that teaching practices are flexible in nature, and when necessary, there is a need to alter or completely replace them to meet educational outcomes.

This highlights a significant responsibility on the teachers that goes beyond being moderators, facilitators, or advisors, as suggested from the CABLS blended instruction model. Instead, their roles extend to knowledge building as they deliberately reflect on and refine practices to promote knowledge building during teaching and learning processes. Furthermore, focusing on the reflective practices as enablers of integrative knowledge building reveals a direct link between the teacher, content, and underlying practices. This interplay is made visible through autonomy pathways, which showcase how the teachers work with the content and the structure that underpins their practices to effectively deliver content to the learners.

(ii) Purposive teaching practices

Purposive teaching practices were observed through intentional autonomy code shifts based on specific activities going on during instruction. For example, all teachers remained within the sovereign codes when explaining concepts in relation to given class work activities or rectifying content knowledge. This indicates an intentional focus on disciplinary engagement so that the target content and purposes are achieved or maintained in the lessons. The rectification of content within the sovereign code grounded explanations relating to corrections within the technical science curriculum, clearly aligning with the educational goal of fostering understanding of science concepts. Purposive practices were also observed when teachers opted to introduce new concepts, consolidate understanding, reinforce disciplinary skills, and deepen understanding within the sovereign codes. The teachers connected the target content to other knowledge forms and enforced assessment strategies within the projected codes as observed in CT1, CT2, and CT4. Everyday explanations and explanations aimed at extending knowledge were intentionally explained within the exotic codes in CT2, while introjected codes fostered a link between everyday understanding and operations for learning the target content, as seen in CT2.

The intentional focus on different codes illustrates the strategic attempt to seek various knowledge forms, which are then integrated to enhance scientific understanding of target concepts. In most cases, these shifts were brief and purposeful, as in the case of CT2, where the teacher weakened and strengthened positional autonomy overtime in the lesson to establish an entry point grounded on everyday knowledge for learners to understand the target content.

The purposeful integration of various forms of knowledge highlights that integrative knowledge building can be successful when lessons are designed with intentionality. In the observed lessons, these purposive shifts were mostly prevalent in the CT2 lesson, as frequent shifts were highlighted through dynamic autonomy pathways indicating greater opportunities for integrative knowledge building.

(iii) Interdisciplinary and contextual learning

The observed shifts between different codes in the lessons highlight interdisciplinary and contextual learning. In the CT1, CT2, and CT4 lessons, interdisciplinary engagement was noted when teachers used operations from other domains to enhance target content learning. For example, mathematical procedures and physical science ideas facilitated interdisciplinary learning, thus demonstrating that science concepts are not completely separate from other disciplines. Contextual learning is evident in the CT2 lesson through the ongoing interplay between target and non-target content, which was introduced to assist learners in connecting scientific concepts with concepts and procedures they are familiar with from their everyday experiences. Both interdisciplinary and contextual practices established greater opportunities for integrative knowledge building since learning of the target concepts was not segmented.

(iv) Learner-centred approaches

Learner-centred approaches are imperative as they ensure that instruction is rooted in practices that enable learners to engage with the content. In these lessons, learners' active participation acted as the key feature for promoting integrative knowledge building. For example, in the CT1 and CT2 lessons, learners' questions prompted teachers to shift between various autonomy codes during instruction. In one instance from the CT1 lesson, the teachers' focus had shifted from the target and was grounded on behavioural issues for an extensive period. A question from a learner redirected the focus back to the targets, thus establishing a focus on the lessons' objectives. As expected in contact sessions, disruptions from learners are inevitable. However, it is important for teachers to address such issues without significantly detracting from the objectives of the lesson.

In another instance in the CT2 lesson, learners responded incorrectly to the questions posed by the teacher. This necessitated a series of weakening and strengthening of PA and RA to enable learners to grasp the content. Such an instance highlighted the relationship between the learners and the content, which then informed the practice chosen. Again, in the CT2 lesson, learners' responses were used as a foundation to introduce key concepts as the teacher scaffolded understanding based on prior knowledge. This occurrence demonstrated the benefits of valuing learners' input to build knowledge which is integrative. The above-mentioned examples underscore the role of learners in prompting autonomy code shifts, which are significant in integrative knowledge building.

While learners are the key contributors in these shifts, teachers play a central role in deciding how they respond to learners' inputs. For instance, in the CT1 lesson, the teacher intentionally chose not to shift codes to accommodate a question that was entirely outside the scope of the lesson. To maintain the balance between learner centred approaches and the focus on the target content, this decision was crucial. This example further highlights that the presence of learners can act as both an enabling and a constraining factor of integrative knowledge building. This means that in some instances destructive engagements can be noted and if teachers are not careful these can affect how effective integrative knowledge building occurs. Thus, teachers must carefully navigate classroom dynamics without wondering too far from the lessons' objectives. Once again, the role of the teacher extends beyond aspects mentioned in the CABLS model.

5.5.1.2. IKB constraining practices in contact sessions

(i) Passive learning

In contrast, passive learning constrains integrative knowledge building. As in the case of the CT3 lesson, less interactions were observed, and the teacher remained within the same code (sovereign). The emphasis was primarily on transmitting target content and addressing behavioural issues. While this approach ensured that learners' understanding is grounded in scientific concepts, the lack of using learners' cues and prompts as a means to venture out to other knowledge sources restricts the learners' ability to effectively comprehend science concepts.

(ii) Subject centric focus

Subject centric focused emerged as one of the integrative knowledge building constraining practices. This was noted mostly in the CT1 and CT3 lessons. In this type of practice, the focus is entirely on the target content and purposes as a result throughout the entire lesson the teacher stays within the sovereign codes. This approach can often lead to fragmented learning experiences, where knowledge is presented in isolated segments. Such practices again present issues of segmented learning where learners may view knowledge as unrelated entities that cannot be brought together during instruction.

(iii) Pedagogically risk-averse practices

Additionally, pedagogically risk-averse practices also constrain integrative knowledge building. In such practices, teachers usually maintain codes that they are comfortable with, driven by the fear of the implications of diverging to other codes. For example, in the CT1 lesson, limited autonomy shifts are noted, and the teacher mentioned during the post-interview that incorporating everyday examples (i.e., shifting to exotic codes) can potentially result in misconceptions. This reflects a belief that diverging to other codes can have both positive and negative impacts; thus, the teacher avoids any risk-taking practices entirely. While this concern is justified, it should not be the sole reason resulting in restricting knowledge building in lessons, rather teacher ought to be deliberate in their practices and anticipate outcomes. In that way teachers would be able to navigate any code without the fear of theoretically losing learners in relation to the content being taught. Of importance is the need for teachers to recognise that teaching is a complex process, and thus the practices that they may opt for should be intentionally designed to meet educational outcomes.

5.5.2. Key knowledge practices in online sessions

Similar to contact sessions, stay pathways, return trips, complete tours and dynamic tours were noted in online lessons. A detailed analysis of these pathways highlighted autonomy pathways that enabled or constrained integrative knowledge building. For instance, OT1 demonstrated greater potential for integrative knowledge building through successfully transitioning through all four autonomy codes, resulting in dynamic shifts on the autonomy plane and pathways. Though not similar to OT1, OT4 through a complete tour between three autonomy codes exhibited successful integration of other knowledge forms. In contrast, lessons from OT2 and OT3 presented limited integrative knowledge building opportunities for learners. For example, for OT2 a return trip between two codes namely sovereign and exotic was noted. Movement between these two codes limited the instruction to disciplinary understandings (sovereign) and, briefly on everyday knowledge (exotic). On the other hand, OT3 remained within the sovereign codes throughout the lesson, constraining integrative knowledge building.

While the analysis of autonomy pathways provides a comprehensive and visual representation of how autonomy codes were enacted in these lessons, the specific practices that led to these observed shifts remain unclear in online contexts. Through pulling everything together from the pathways, detailed in the previous section, a deeper understanding of the knowledge practices informing these shifts can emerge. This in turn highlights the knowledge practices that either enable or constrain knowledge building in online sessions. Figure 37 below provides an outline of the knowledge practices identified in the online sessions. These practices are categorised as either enabling or constraining factors for integrative knowledge building (IKB).

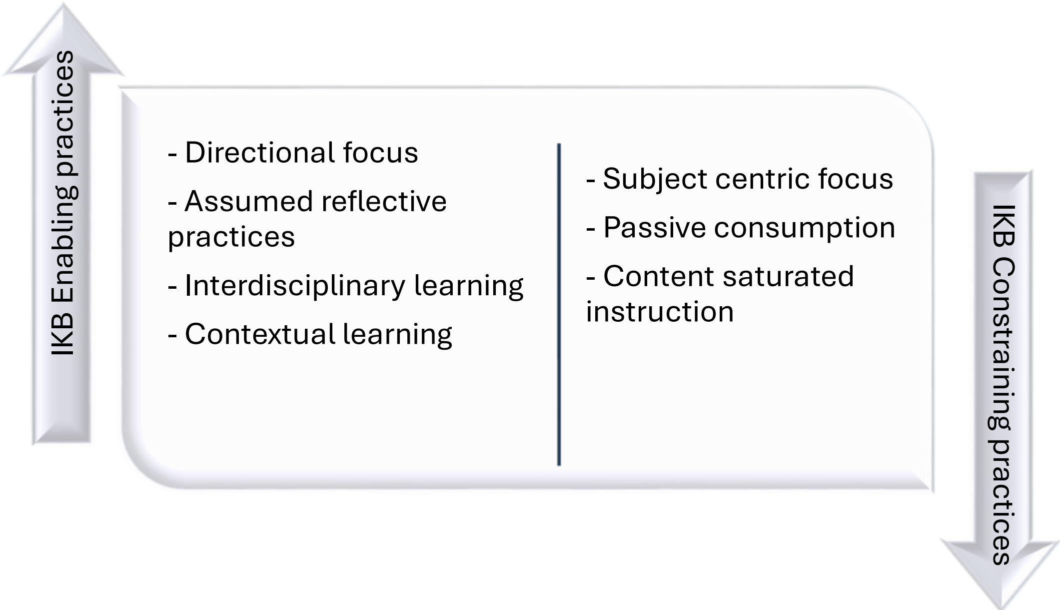


Figure 37: Integrative knowledge-building (IKB) practices in online sessions

5.5.2.1. IKB enabling practices in online sessions

For online sessions, four practices emerged as enablers of integrative knowledge building while three practices were identified as integrative knowledge building constraining practices as outlined in figure 37 above. The sections that follow provide details on factors that contributed to the identification of the above outline practices.

(i) ***Directional focus***

Directional focus emerged as a key factor enabling integrative knowledge building (IKB) in online lessons. Directional focus in the context of this study explains practices that explicitly outline what is being taught and why. In other words, the teacher clearly clarifies the objectives of the lesson. As emphasised through the CABLS blended learning model, teachers take the role of being guides on the side. In the context of this study, this guidance is complex as it expands into guiding learners to navigate content that transcends beyond a focus on the targets.

As in the case of OT1 and OT4, through outlining the objectives of the lesson, teachers would establish an entry point into the lesson, initiating shifts that began with stronger positional autonomy (PA) and relational autonomy (RA). Following this, teachers would strategically weaken either PA or RA, or both to enable learners to connect target concepts and purposes with non-target content. This approach facilitated significant shifts between autonomy codes over time, with teachers at times simply re-emphasising the learning objectives to mark or trigger transitions into other codes.

It was noted though that not all instances where the teacher clarified objectives resulted in successful autonomy code shifts. For example, in the OT3 lesson, despite repeated emphasis on lesson objectives, the directives given did not result in movement across autonomy codes. However, the lesson remained limited to the sovereign codes, demonstrating that just stating objectives was insufficient. The observations from OT3 suggests that teachers ought to adopt strategic approaches that ensure that objectives serve as catalysts for autonomy code shifts rather than static markers of content coverage. This further suggests the need for online teachers to provide cues and directions that extend beyond mere guidance thus expanding the general role of the teacher in online contexts. In asynchronous contexts, guidance should assume extended roles and actively facilitate shifts across autonomy codes. Effective directional focus in online instruction, therefore, involves not only directing learners' attention but also incorporating cues that enable for the continuous integration of knowledge from other sources.

(ii) Assumed reflective practices

Since real-time engagement is limited in asynchronous contexts, assumed reflective practices were evident in some of the lesson. The ability of the teacher to presume what learners might be thinking or how they might be connecting prior knowledge to new content enabled significant shifts in autonomy codes. For instance, OT1, prompted learners to consider their prior conceptions in relation to the target content. Since learners could not directly engage with the teacher in real time, the presumed possible responses allowed the teacher to tap into exotic codes. Assumed reflective practices highlight the teacher's ability to recognise the absence of direct interaction and create alternative engagement strategies. For instance, in some lessons, mental engagement practices in the form of rhetorical questions asked by teachers allowed learners to reflect and mentally engage in the lesson. This was noted in OT1, OT2 and OT4. Through asking rhetorical questions, teachers were able to establish shifts in autonomy based on the questions asked. Some questions establish an entry point into the target content (OT2) while other questions allow the teachers to venture out to other knowledge sources (OT1 and OT4).

By establishing such strategies, the teacher created an entry point into learners' thought processes, which was key in enabling integrative knowledge building. In addition, rhetorical questions allowed for a conversational tone and in some instances the teachers would give specific cues that took a conversational approach to guide learners through the content. In OT4 lesson specific interactive phrases which maintained significant shifts in autonomy codes were observed. For example, the conversational tone and interactive phrases used by OT4, such as "*actually, you can pause the video and do it now*," created a sense of real time engagement which was critical in maintaining a stay within slightly weaker PA and RA at that point in time in the lesson.

Beyond facilitating autonomy shifts, reflective practices indicate an adaptive teaching strategy essential for asynchronous contexts. Since learners engage with content independently, teachers must anticipate potential responses and create prompts that enhance learning. This approach not only enable integrative knowledge building but also enhances cognitive presence and teacher presence identified through the Col model (Chapter 2). Learners are required to construct meaning through continuous reflection and dialogue which was observed in teachers who opted for reflective practices. The presence of the teachers in directing the learning process also played an imperative role in these contexts. By embedding reflective practices in online sessions, teachers can enhance deeper learner engagement in asynchronous contexts while facilitating autonomy shifts for integrative knowledge building.

(iii) *Interdisciplinary and contextual learning*

Similar to contact sessions, interdisciplinary and contextual learning practices emerged as key enablers of integrative knowledge building. These practices were evident in OT1 and OT4, where teachers drew knowledge from different domains other than the scientific discipline (interdisciplinary). In other cases, teachers would ground learning to knowledge forms that learners are familiar with (contextual). In OT1, for instance, the teacher deliberately used analogies that connected the lesson to familiar experiences. Similarly, in OT4, the teacher revisited learners' prior knowledge, using familiar examples that learners could relate to. Doing so established shifts in autonomy codes as target and non-target content and procedures were integrated. This further allow learners to view science concepts as interconnected and relevant to their everyday lives.

5.5.2.2. IKB constraining practices in online sessions

(i) *Passive consumption*

Passive consumption emerged as one of the practices in online sessions that constrained integrative knowledge building. While this is similar to passive learning observed in contact sessions, the key difference in online environments lies in the lack of real-time engagement. Teachers engaging in passive consumption practices often chose to passively relay content to learners without providing reflective prompts. In such instances, learners were left to passively absorb the content with limited opportunities to interact with the target concepts. For instance, in the OT3 lesson, passive consumption was particularly evident and contributed to a lack of shifts between autonomy codes. The lesson leaned heavily on teacher centred instruction in which the focus was on transmitting content knowledge. Doing so resulted in higher levels of positional autonomy (PA) and relational autonomy (RA).

In such instances, learners were not provided with the opportunities for mental engagement through questions or reflective activities. In an attempt to mitigate passive consumption of content, CT3 promoted interactions that followed a traditional format. Here, the teacher posed questions and then provided correct answers without giving learners a chance to cognitively engage with the content. Providing responses was expected since learners could not engage in real time considering that this was an asynchronous lesson. However, strategic efforts to provide reflective practices involving assumed responses could have enabled the teacher to mentally engage learners thereby influencing shifts in autonomy codes.

Passive consumption practices constrain integrative knowledge building because they limit the dynamic shifts between autonomy codes through maintaining a focus on the target content rather than encouraging learners to question or apply what they have learned. When a comparison between lessons that engaged in passive consumption practices and reflective practices is pulled, it is clear that for teachers engaging in reflective practices, they would either shift towards stronger or weaker PA and RA as an effort to encourage learner reflection and mental participation with the content. This further consolidates the importance of structuring lessons in a way that promotes learner participation through reflective practices. Doing so, would allow for thorough processing of the content while at the same time allowing teachers to incorporate knowledge from diverse sources.

(ii) *Content saturated instruction*

OT3's approach reflected a pedagogical oversight, as the asynchronous nature of the session led to an overload of content delivered within a short duration. This practice, termed content-saturated instruction, involves bombarding learners with numerous concepts related to the targets within a limited timeframe. As observed in OT3, such an approach constrains integrative knowledge building, as the focus shifts to simply covering the curriculum scope, leaving limited opportunities for helping learners engage in meaning-making processes or exploring other knowledge sources. In OT3 such a practice resulted in the teacher staying with the sovereign codes where positional and relational autonomy remained stronger throughout the lesson.

OT3 teacher justified this approach by stating that preparing learners for exams is necessary. Although this explanation made logical sense, considering that the learners taught were grade 12 learners, the justification undermined the goal of providing learners with interdisciplinary knowledge forms necessary to enhance understanding. It is clear from the autonomy pathway for OT3, which was determined as a stay pathway that rote learning can restrict the ability of learners to explore knowledge from different domains. This observation underscores the need for online teachers, especially in asynchronous contexts, to be intentional and strategic in their teaching practices. If the goal is integrative knowledge building, educators ought to design lessons that allow for deeper engagement, reflective thinking, and the exploration of diverse knowledge sources, rather than simply rushing through content. Doing so commonly leads to a subject centric focus which is already identified as one of the practices that constrain integrative knowledge building from the contact sessions analysis.

(iii) *Subject centric focus*

Subject centric focus as noted in contact sessions also emerged as a constraining factor in online sessions. As previously outlined in subject centric practices, teachers often focus on the target content and purposes resulting into a stay within the sovereign codes throughout the lesson. For instance, in OT3 lesson, the teacher focused on subject specific content which resulted into a stay pathway as identified in the previous sections. Similarly, in OT2, despite the ability of the teacher to shift to the exotic codes resulting in a return trip, the sovereign code remained dominant thus grounding most parts of the lesson with ideas of stronger positional autonomy (PA) and relational autonomy (RA).

In an attempt to mitigate the subject centric focus in OT2 lesson, the teacher used rhetorical questions. Although rhetorical questions have already been identified as approaches fostering reflective practices which are key in enabling integrative knowledge building. In OT2 the questions asked where limited in mental engagement as they were aligned directly to the target content with limited opportunities for learners to engage with the content beyond the target. The rhetorical questions in this case failed to facilitate meaningful shifts between autonomy codes thereby reinforcing a subject-centric approach. Subject centric practices are necessary to help learners master the target content and purposes however overly focusing on the subject specific content often leads to segmented learning. The strong focus on target content focus limits learners' abilities to explore knowledge from their experiences or drawing from other disciplines. This impedes on the general understanding of the subject matter leading to undesirable outcomes.

5.5.3. Comparative analysis: contact vs. online knowledge practices

The comparative analysis of contact and online knowledge practices reveals that there are practices that are unique to the context whereas some practices are shared across modalities. In the previous sections a generic outline of the practices was highlighted. However, this section shifts focus to a detailed comparison which is necessary to clearly map essential practices in blended learning contexts. Firstly, this section begins by showing overlaps in knowledge practices that enable integrative knowledge building followed by those that constrain integrative knowledge building in both modalities. Figure 38 below highlights enabling integrative knowledge building practices.

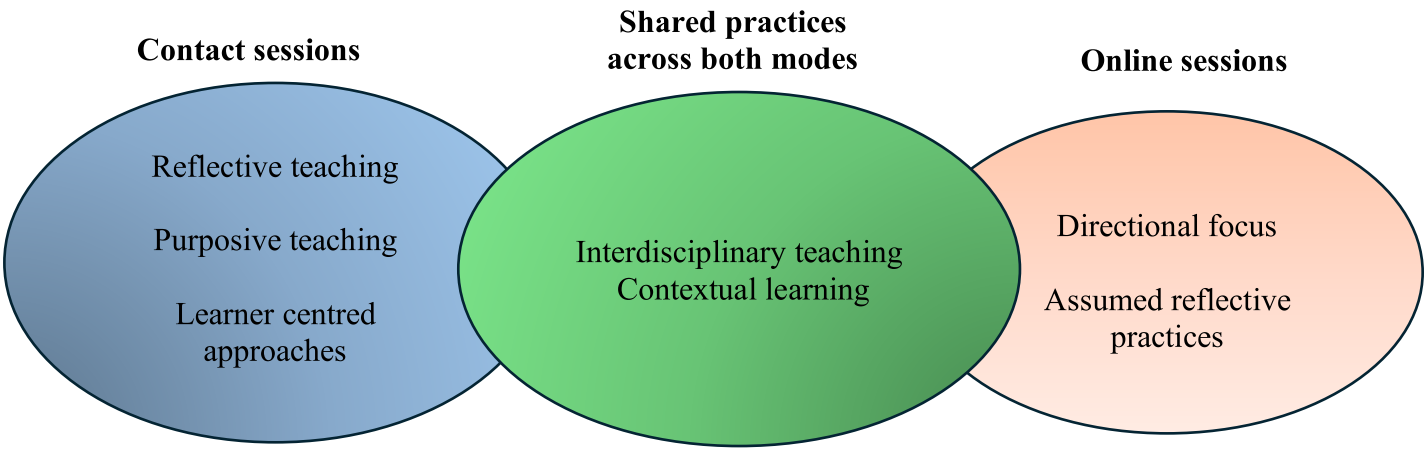


Figure 38: Overlaps in IKB enabling practices

Based on the figure above, it appears that interdisciplinary learning and contextual learning practices were shared across contact and online sessions. This entails that both modes encouraged cross-disciplinary connections, which facilitated broader knowledge integration. Additionally, learning was anchored in real-world contexts, promoting relevance and at the same time shunning away from the issue of segmented learning. Teachers engaging in interdisciplinary and contextual practices often emphasised the use of analogies, familiar examples and diagrams as well as macroscopic representations in their lessons.

As previously outlined, reflective teaching, purposive teaching and learner centred approaches were unique to contact sessions whereas directional focus and assumed reflective practices were unique to online sessions. What distinguished reflective teaching and assumed reflective practices as outlined in contact and online sessions respectively was the context. In reflective teaching, teachers would reflect in action based on learners' responses, attitudes and reactions to the content presented in the lesson. Following this, teachers would respond instantly by weakening or strengthening PA and RA as required. In assumed reflective practices, since the lessons were pre-recorded, teachers anticipated learners' thought processes and acted on the assumed responses to either weaken or strengthen PA and RA. What stood out was that, regardless of whether the reflections were assumed or not, teachers ultimately tapped into various knowledge sources, ensuring that learners engage with diverse knowledge forms.
When it comes to integrative knowledge building constraining practices, in both modes' subject centric focus and passive engagement were shared across contact and online sessions. Both contact and online lessons displayed tendencies to limit learning within subject boundaries, hindering cross-disciplinary knowledge integration. Furthermore, in both modes, learners were perceived as passive recipients of knowledge, and this limited the ability of the teachers to shift across various autonomy codes. As noted in lessons that valued learner centred approaches, learners would act as catalysts towards shifts in autonomy codes through asking questions that

either enabled the teacher to weaken or strengthen PA and RA. At the same time, pedagogically risk-averse approaches and content saturated instruction practices were unique in contact and online sessions respectively. Figure 39 below offers a visual representation of the overlaps in integrative knowledge building constraining practices.

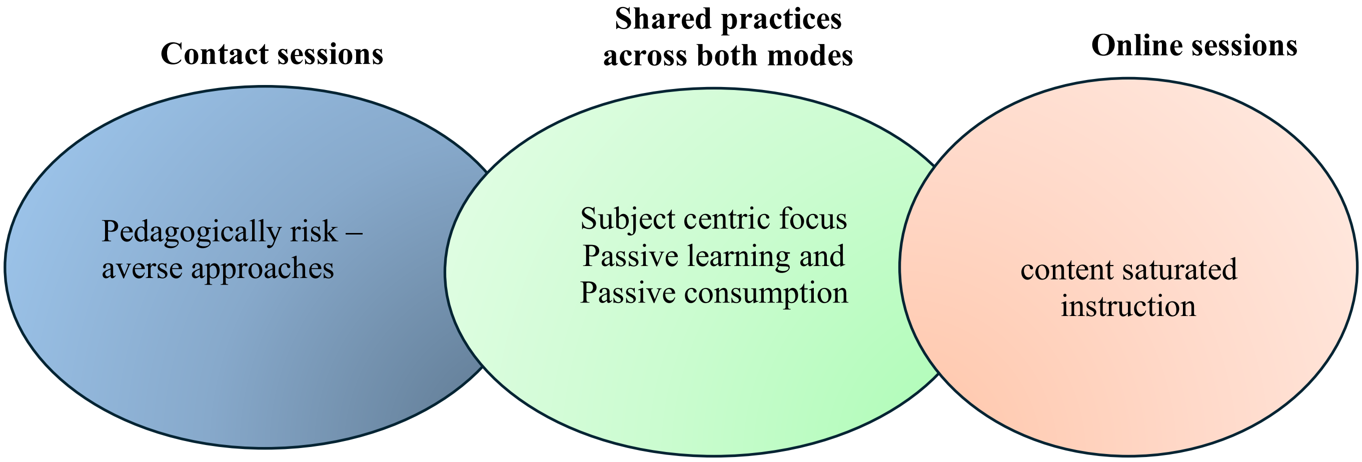


Figure 39: Overlaps in IKB constraining practices

5.5.4. Effective knowledge practices for integrative knowledge building in blended instruction

The effective knowledge practices for integrative knowledge building in blended instruction are a synthesis of enabling practices observed across both contact and online settings. The main argument is that these practices should intentionally be incorporated in instruction if the goal is integrative knowledge building in blended contexts. A key practice is interdisciplinary learning, which is a practice that promotes a connection of knowledge between different domains. Interdisciplinary learning as previously mentioned promotes learning that expands beyond the targeted knowledge thus helping learners to apply concepts in broader contexts. Equally important is contextual learning, where real-world applications and examples are used to ground theoretical concepts, enhancing relevance and transferability of knowledge.

As previously outlined both interdisciplinary and contextual learning practices emerged as shared practices in contact and online sessions. This highlights their significance in facilitating knowledge building in blended contexts. This further suggests that a blended learning environment designed to support integrative knowledge building must intentionally prioritise these practices. Doing so would ensure that learners make meaningful connections between the target knowledge and knowledge from other disciplines. At the same time learners may be able to apply content taught in the classroom to diverse and authentic contexts. Such a pedagogy escapes issues of segmented learning as knowledge learned becomes relevant and relatable to other knowledge forms.

Additionally, reflective teaching which was explicitly observed in contact sessions and implied in online sessions plays a vital role in promoting knowledge that is integrative. Through fostering cognitive engagement in both online and contact sessions, reflective teaching emerges as one of the essential practices. Blended learning models such as the Community of Inquiry (CoI) model emphasise the need for teachers to facilitate cognitive engagement in blended contexts. Even though the model underscores this importance, it does not clearly reveal how this can be achieved in practice. A focus on knowledge practices inherent within blended contexts helps shed light on how teacher can tap into this cognitive engagement element in blended instruction. For instance, the findings of this study highlight reflective teaching as a foundational knowledge practice, offering teachers a tangible starting point where cognitive engagement is concerned.

Furthermore, purposive teaching practices in which teachers become deliberate in terms of activities and processes taking place during instruction is identified as a practice essential for integrative knowledge building in blended instruction. Purposive teaching practices highlight the interplay between content and pedagogy as factors influencing IKB. For example, teachers would remain within the sovereign codes to explain concepts or introduce new concepts. In some instances, they would switch to the exotic codes to expand knowledge. This strategic approach ensures that integrative knowledge building strategies are intentionally selected to enhance learning in blended context. The intentional strategies opted for immediately provides the teachers with an essential role that goes beyond moderation and facilitation as outlined through the CABLS model. This further highlight that in blended instruction the teacher's role is dynamic and cannot be reduced to linear roles. Teaching is a complex activity as such blended learning models ought to take a holistic approach that explicitly reveal how teachers work with knowledge in these contexts.

In addition, learner-centred approaches are necessary to building knowledge that is integrative. For instance, learners' questions and incorrect responses necessitated shifts in autonomy codes, thereby promoting integrative knowledge building. Learner centred practices highlight the interplay between learners and content, aligning with the CABLS model and the Community of Inquiry (CoI) model, both of which position learners as active participants in the learning environment. Even though learner centred practices were noted, it remains notable that the role of the teacher undeniably played a huge role in facilitating autonomy shifts. This means that before the learner, the teacher serves as the primary enabler of integrative learning in blended learning contexts. Notably, blended learning models relegate the role of the teacher by prioritising learners and the technology (as in the case of the SAMR model). Finally, directional focus which was observed in online sessions emerges as an essential knowledge for integrative knowledge building in blended contexts. Directional focus describes a practice where teachers emphasised key objectives of the content throughout the lesson. This ensured that an entry point into the target content and purposes was established.

Pedagogically, the enabling practices for integrative knowledge building as derived in online and contact sessions highlight the need for teachers to focus on the strengths of each mode. Moreover, an explicit understanding of these practices positions the teachers in a position where they can make informed decisions relating to how each practice can be modified or leveraged to suit specific needs in blended contexts. This then allows a community of teachers to adopt common frameworks that are useful in specific contexts. For an example directional focus which is a key strength in online sessions can also be integrated in contact sessions. This would assist in providing clarity and grounding the lesson first within the target concepts prior to any weakening of positional and relational autonomy. Leveraging this practice in contact sessions can help in extending the potential of contact sessions as a constituent of blended instruction to expand on sources for integrative knowledge building.

In another example, learner centred practices which are more pronounced in contact sessions can be adapted to online sessions through deliberate strategies that promote learner participation in asynchronous modes. Adopting such practices would ensure that integrative knowledge building potentials facilitated through learner participation can be embraced in blended contexts. For example, in asynchronous lessons, teachers could adapt their strategies by incorporating discussion forums. Such strategies would allow learners to pose questions that learners and teachers can collectively respond to. By analysing these discussions, teachers can intentionally weaken or strengthen positional and relational autonomy as required. Insights on knowledge practices useful in blended instruction necessitate a conversation about general implications for teacher's professional knowledge and pedagogical approaches if educational institutions aim to focus on practices that build knowledge that is integrative in blended instruction.

5.6. Developing the blended learning integrative knowledge-building model (BLIPM)

The previous sections highlighted how integrative knowledge building occurs in online and contact sessions as constituents of blended instruction. The sections further identified the dynamics and specific processes that facilitated or hindered integrative knowledge building in these contexts. The findings drawn from all the previous sections are then used to establish how a blended learning pedagogical integration model in science education can be constructed to enable integrative knowledge building in blended instruction.

Three sets of necessary information emerged from the data sets of the study. Firstly, information about autonomy pathways and their potential for integrative knowledge building in both online and contact sessions. This information is necessary as it gives insights on IKB constraining and enabling practices. Secondly, information about essential knowledge practices in blended contexts as derived from enabling knowledge practices from both contact and online sessions. Thirdly, subsumed information about what the practices mean for teachers' professional knowledge and pedagogy in blended contexts. These three sets of information are used as significant information that informs the design of proposed model.

It was argued from the onset that the enthusiasm to adopt blended instruction as a current and future teaching method should be accompanied by a thorough examination of the models that govern learning in these contexts. It was further argued that the current and widely accepted blended instruction models fail to explicitly encompass how teachers work with knowledge or clearly show the knowledge practices that are embedded within blended learning contexts. The presented arguments led to a proposition of a model that addresses the multifaceted role of science educators in facilitating and building knowledge that is integrative within blended learning contexts. Such an understanding is argued to be crucial in providing educators with crucial knowledge they may require if the goal is integrative knowledge building in blended contexts.

5.6.1. Informants of model design

The proposed model is informed by the empirical data from classroom observations, pre-recorded video observations and interviews. Given that this study was informed by specific teacher observations in both contact and online modes, the data presented offered a snapshot of distinct knowledge practices as they emerged in these instructional settings. The observed knowledge practices were influenced by multiple factors, including autonomy pathways and their potential for integrative knowledge building, the teacher's role in shaping these pathways, and the extent to which learners contributed to them. These elements collectively informed an understanding of effective knowledge practices for blended instruction, drawn from the enabling and shared practices identified in each mode.

From the results outlined about knowledge structuring patterns, autonomy pathways and knowledge practices, subsumed aspects such as teachers' professional knowledge and pedagogical approaches were identified as pre-requisites for integrative knowledge building in science education. For example, the ability of the teachers to shifts autonomy codes was also dependent on their knowledge base in relation to the content (professional knowledge) or their ability to use learners as prompts for these shifts (pedagogical approaches). Given the nature of the data collected in this study, the proposed model is designed as a theoretically descriptive model rather than a prescriptive or operationalised model. The proposed model thus articulates the integrative knowledge building processes and frameworks that support the integration from a theoretical perspective as generated from the data sets. This implies that the model serves as a conceptual nucleus to stimulate discussions and generate insights into integrative knowledge building processes by emphasising how they can be made visible and incorporated within blended learning contexts , particularly in the science education domain.

5.6.2. Theoretical and conceptual foundations of the model

5.6.2.1. Purposes and objectives

The purposes and objectives of the model stem from the results generated from the other secondary research questions. These purposes are outlined as follows:

i. To contribute theoretically by providing an empirical research-based framework that advances understanding of blended instruction beyond technology use and the role of learners in these contexts. The model addresses the limited role of teachers in blended contexts, arguing that where integrative knowledge building is concerned, the teacher takes a complex role that includes being a knowledge builder. Purposefully selecting strategies that support integrative knowledge building.

ii. To serve as a guide for science educators on how to structure and refine blended instruction strategies, taking into account the opportunities offered by both contact and online sessions.
iii. To empower science educators by equipping them with an extensive understanding of knowledge practices and how to integrate them effectively into their blended teaching approaches.

Given the purposes of the model, the objectives can be summarised as follows:

i. To develop a framework that explicitly reveal and guide science teachers on how to work with knowledge in blended contexts clearly highlighting the knowledge practices inherent in these contexts. This understanding stipulates the relationship between the teacher, context, content and pedagogy. The interplay between these variables goes beyond the role of learners in blended contexts (CABLS & Col) and the use of technology (SAMR) and provides a pedagogical starting point where integrative knowledge building is concerned.
ii. To support meaningful blended learning by ensuring that blended learning is not just a combination of online and face-to-face instruction but incorporates explicit knowledge-building processes and practices that exhibit strengths from each mode.
iii. To enhance teacher pedagogical strategies by providing teachers with a structured approach to facilitating blended learning that actively engages learners in knowledge building processes.

5.6.4. Design specifications

5.6.4.1. Assumptions, attributes and limitations

Since this thesis is grounded in the interpretivism paradigm, which sees social reality as a dynamic process shaped by the individuals involved, it adopts this lens to examine how various forms of knowledge practices within online and contact sessions influence the effectiveness of blended instruction. By making these knowledge practices explicit it becomes possible to refine existing models or introduce new perspectives that enhance their structural and pedagogical efficacy. Beyond the need to understand knowledge practices, this study critically examines the role of teachers in blended instruction. Existing blended learning models often relegate the role of the teacher by treating them as secondary contributors where teaching and learning is concerned. As previously mentioned, the role of the teacher includes active knowledge building during instruction. The theoretical assumptions guiding this study underscore the importance of restoring teachers' power through enabling them to make informed decisions about their instructional approaches. When knowledge practices are visible teachers are better equipped to engage more effectively in integrative knowledge-building processes through adopting framework that support the integration. This may enhance the pedagogical potential of blended instruction. The Blended Learning Pedagogical Integration Model (BLPIM) is thus developed based on the following assumptions:

i. ***Understanding and leveraging knowledge practices in blended contexts:*** The model assumes that effective integrative knowledge building in blended learning requires a deep understanding of the distinct knowledge practices in contact and online sessions. The model emphasises the need for educators to strategically leverage and adapt the strength of each mode to meet diverse integrative knowledge building needs

ii. ***Teachers' awareness of knowledge practices/forms enhances student learning:*** The model assumes that when teachers are knowledgeable about the structures of content and how various parts of knowledge relate, they are better equipped to guide students in understanding the interconnectedness of concepts.

iii. ***Empowering science educators through knowledge practices***: The model assumes that empowering teachers with a comprehensive understanding of knowledge practices is important. The assumption is that such an understanding may be accompanied by effective practical implementation of effective knowledge practices in blended contexts. Understanding coupled with implementation may lead to enhanced pedagogy in blended settings. Teachers are viewed as key experts in their classrooms, thus providing them with the necessary tools for knowledge integration can help them improve their teaching strategies for better student outcomes.

iv. ***Teachers as knowledge builders:*** The model assumes that for teachers in blended learning contexts, their role is more than just facilitation, moderation, advising nor guiding learners in the learning processes. It also goes beyond that of a technological expert, as suggested in the SAMR model. Teachers are active knowledge builders who are consciously aware of their knowledge-building practices. In the process they use their skills to actively engage learners in the co-construction of knowledge. This assumption highlights the dynamic role teachers play in fostering meaningful integrative knowledge building learning experiences.

v. ***Ongoing professional development for educators:*** The model assumes that continuous professional development is essential for educators to improve their practices. Professional development aimed at helping teachers expand their knowledge base and refine pedagogical strategies where integrative knowledge building is concerned is a necessity. The findings in the previous sections revealed that for teachers to successfully integrate interdisciplinary knowledge forms they first need to expand their knowledge base beyond the subjects they teach.

5.6.5. Core Components of the BLPIM Model

The model for BLPIM is framed around the four major components which are derived from the major findings of this thesis.

- ***Autonomy pathways in blended instruction***: An analysis of both online and contact modes revealed pathways that enable integrative knowledge building (IKB) in each modality. These pathways were ranked based on their strengths, providing an understanding of the essential practices that support IKB in blended contexts.
- ***Explicit knowledge practices for blended instruction:*** Through the analysis of autonomy pathways for both online and contact sessions, this component identifies the knowledge practices that support integrative knowledge building. As emphasised throughout this thesis, explicit knowledge practices are critical in blended contexts to help teachers make informed decisions about the pedagogical strategies they should adopt for IKB. Some knowledge practices are shared across both modalities, while others are unique to each context. The findings indicate that teachers can leverage the strengths of each mode, modifying or adapting their pedagogy where necessary to support the effective integration of knowledge in blended settings.
- ***Framework for transitioning between modalities***: This component defines how shared enabling practices can be effectively embedded to bridge the gap between contact and online instruction. It also highlights the importance of fluid transitions between the two modalities through incorporating practices from one mode to another. For example, the findings suggested that learner centred practices which are more pronounced in contact sessions can be adapted to online sessions through deliberate strategies such as discussion forums to promote learner participation in asynchronous modes.
- ***Integration strategies for blended instruction:*** This component highlights specific strategies that influenced observed knowledge practices in blended contexts. It focuses on practical approaches that facilitate knowledge integration in these settings.

As highlighted from the findings, the strategies used by teachers included using analogies, familiar examples, experiences and diagrams as well as macroscopic representations. Additional strategies such as holding a conversational tone and use of rhetorical questions enabled integration of knowledge.

- ***Training and professional development for educators:*** This component highlights the ongoing need for continuous professional learning and development for educators. To successfully implement blended instruction, teachers must be equipped with the knowledge, skills, and strategies to navigate the complexities of blended learning environments. As subsumed in the findings, teachers who are empowered with the tools for knowledge integration are better positioned to foster integrative knowledge building in their instruction. In simply terms, the goal is to create teachers who actively assume the role of being knowledge builders in blended settings.

5.6.5.1. Interactions of the core components in the BLPIM Model

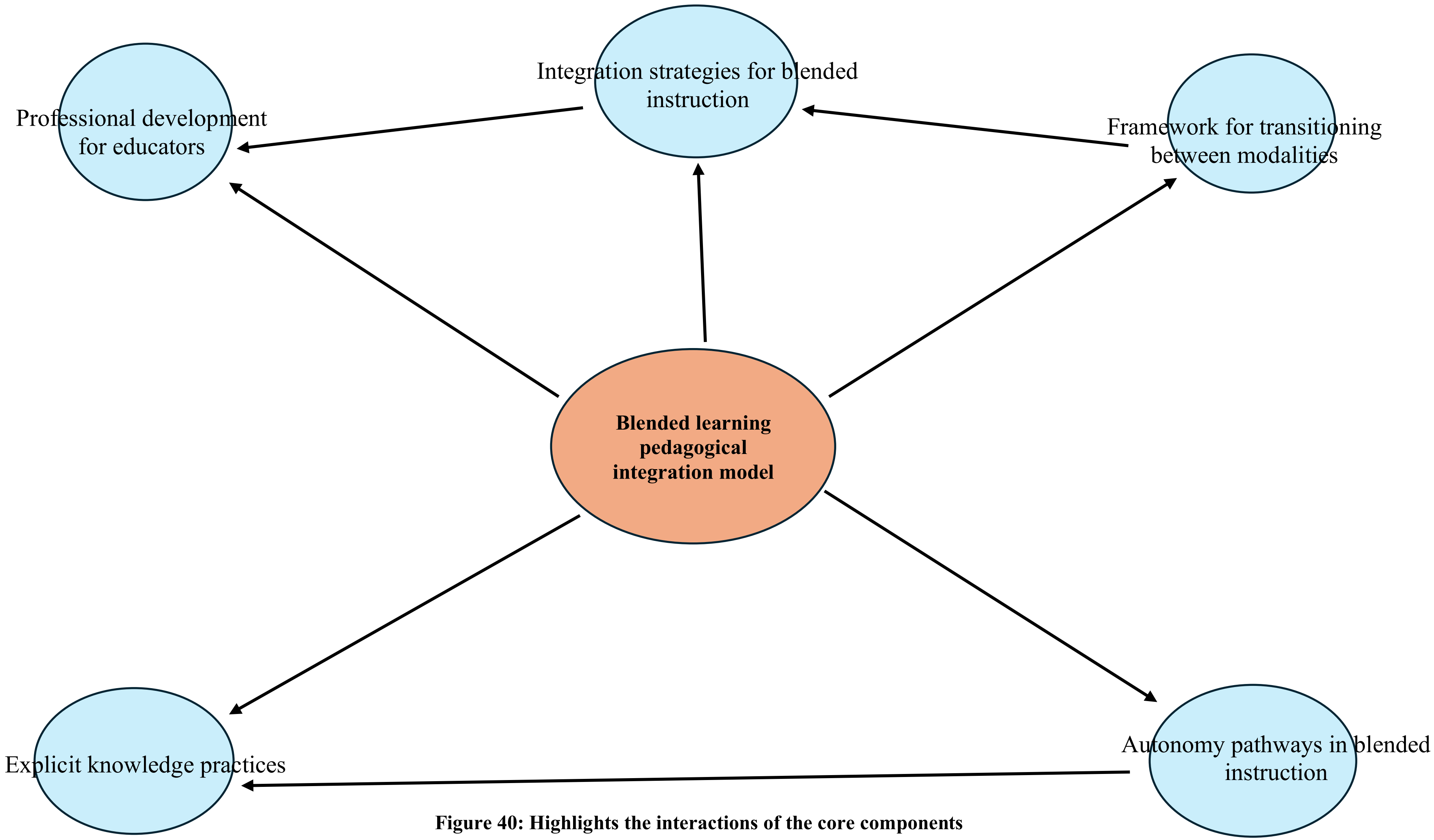


Figure 40: Highlights the interactions of the core components

5.6.5.2. Explanation of the interactions of the core components

The BLPIM model serves as the central framework, influencing the five key components, as illustrated in Figure 40. These components interact in a co-dependent manner, reinforcing each other to create a systematic approach to integrative knowledge building in blended instruction. At the foundation of this model lies the interaction between autonomy pathways and explicit knowledge practices. Establishing essential knowledge practices in blended instruction requires an understanding of the autonomy pathways they opt for in both contact and online modes. As previously highlighted, autonomy pathways played a crucial role in identifying the potential for integrative knowledge building in the lessons observed. However, while these pathways provided insight into how teachers worked with knowledge across different modes of delivery, they did not explicitly reveal the specific knowledge practices applied within these settings. Effective integrative knowledge building practices for blended instruction were framed through an understanding of the pathways observed in the lessons. This highlights a critical relationship: without identifying autonomy pathways, it is impossible to determine the specific knowledge practices adopted during instruction.

The framework for transitioning between modalities, integration strategies for blended instruction, and professional development for educators form the top layer of the BLPIM model. This indicates their rounded role in sustaining integrative knowledge building in blended contexts. Positioning these three components at the top suggests that they build upon the foundational components (autonomy pathways and explicit knowledge practices). Doing so creates a structured and adaptable approach to blended instruction. The framework for transitioning between modalities ensures that enabling practices can be easily adapted across contact and online modes. This is important to encourage effortless transitions between modalities thus enabling teachers to transfer essential knowledge practices from one modality to another.

The transition practices are further reinforced by integration strategies, which provide the practical strategies such as analogies and use of examples to help teachers structure instruction in a way that enables integrative knowledge building. However, the effectiveness of transitioning between modalities and integration strategies depends on professional development. Through continual professional development educators may develop the pedagogical skills necessary to successfully apply transitioning and integration strategies. For instance, teachers must broaden their knowledge beyond their subject matter to effectively utilise everyday analogies or knowledge from other disciplines. This knowledge base may not be readily available thus training may help them navigate the complexities of integrating knowledge in blended contexts. Successful incorporation of integrative knowledge building practices in blended instruction relies on a continuous cycle of refining transition strategies and intentional application of integration strategies. In addition, investing in professional development may enhances teacher expertise thus ensuring successful integration of knowledge in blended contexts.

5.6.6. Input, process and outputs in the blended learning pedagogical integration model (BLPIM)

The BLPIM model operates as a dynamic framework, where key components serve as inputs that drive the process of integrative knowledge building. The inputs ultimately lead to the desired subsumed outputs in blended instruction. The figure below provides a visual representation of the framework.

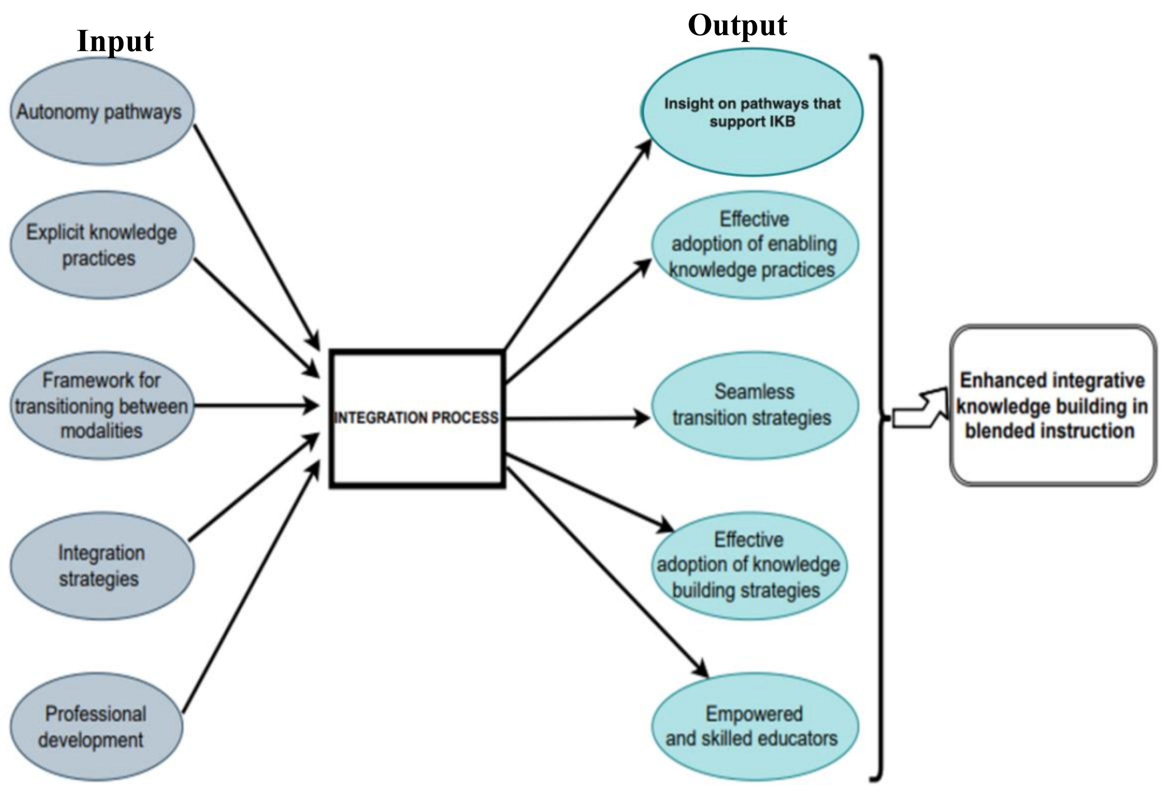


Figure 41: Input-output process of integrative knowledge building in blended contexts

5.6.6.1. Input, process and output model description

The left-side components of the diagram represent necessary conditions for integrative knowledge in blended contexts. Autonomy pathways observed knowledge practices, framework for transitioning between contact and online modes, integration strategies and professional development form part of the model inputs. For example, for integrative knowledge building to occur teachers need to focus on autonomy pathways that support integrative knowledge building. As previously highlighted, dynamic tours, complete tours and partially return trips as observed in both contact and online sessions support integrative knowledge building. These pathways were also identified as key enablers for practices that support integrative knowledge building in blended contexts. At the centre of the model is the process of knowledge integration, which operationalises the inputs leading to the expected outputs highlighted in the figure 41. A dependency relationship exists between input and output with the process acting as the bridge. The right-side components highlight the expected outcomes when the BLPIM process of integration is successfully applied. Overall, outputs are expected to enhance integrative knowledge building in blended contexts. How the components are interrelated is showcased in the systems model as described in the section that follows.

5.6.7. The systems model of blended learning pedagogical integration (BLPIM)

The systems model offers a comprehensive framework for understanding integrative knowledge building in blended contexts. Furthermore, the model highlights the conditions necessary for integrative knowledge building to successfully take place during instruction. Figures 40 and 41 visually illustrate the interconnectedness of the key components of this process showcasing how each element contribute to shape integrative knowledge building experiences during instruction. However, the systems model highlights the dynamic interplay between core and peripheral components, illustrating their collective role in supporting integrative knowledge building. The model presents two interrelated aspects as shown in figure 42 below.

1. Integrative knowledge building processes – this aspect highlights the necessary processes for integrative knowledge building which is essential in revealing knowledge practices embedded in blended instruction.

2. Supporting Frameworks – these provide the necessary structures and strategies ought to be taken to facilitate integrative knowledge building in blended learning environments.

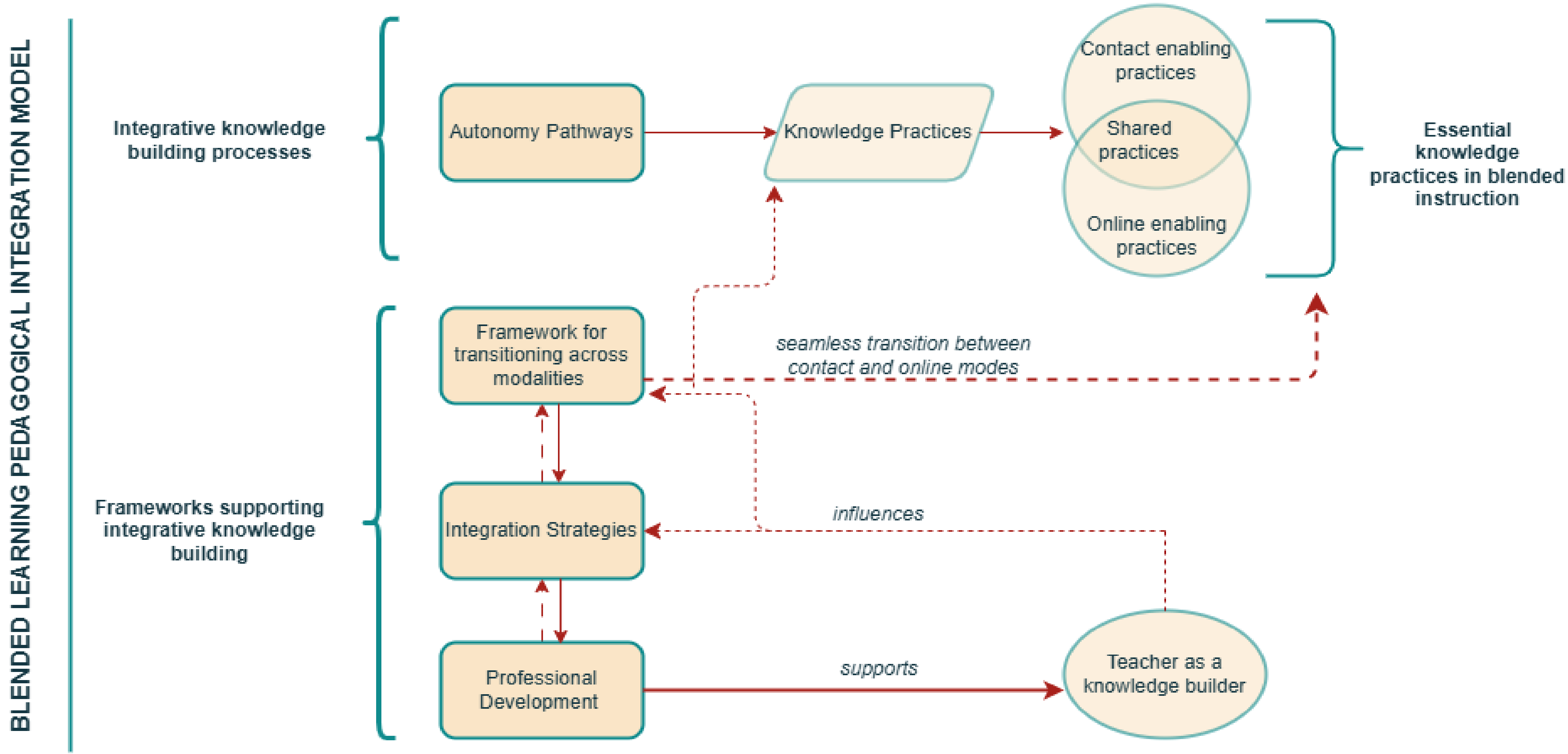


Figure 42: A visual representation of the systems complexity model of integration in blended learning

5.6.7.1. Systems model description

The blended learning pedagogical integration model (BLPIM) in Figure 42 represents a systems approach to integrative knowledge building in blended instruction. It emphasises both integrative knowledge building processes and supporting frameworks. Central to the model are autonomy pathways which facilitate integrative knowledge building in both contact and online sessions. As previously mentioned, various paths traced around an autonomy plane by successive autonomy codes reveal how teachers integrate various knowledge forms during instruction. The findings revealed that in both contact and online modes, dynamic tours, complete tours, and return trips (even though limited in their potential for integration) facilitate integrative knowledge building. As previously mentioned, the autonomy pathways allow us to understand the potential for integrative knowledge building in instruction, however they are insufficient in uncovering the knowledge practices embedded in specific contexts. It was however, revealed that observed knowledge practices depend largely on the autonomy pathways that teachers opted for in their lessons. The model thus highlights a linear relationship between the autonomy pathways and knowledge practices.

To understand or reveal knowledge practices effective for blended instruction, it was necessary to focus only on enabling practices. This is why there is a clear relationship between the knowledge practices and the enabling practices from the model. The findings revealed that reflective teaching, purposive teaching, and learner-centred approaches are enabling practices unique to contact sessions, while directional focus and assumed reflective practices are unique to online sessions. Shared enabling practices such as interdisciplinary learning and contextual learning were noted in both modalities. From the model it is clear that a focus on enabling practices both unique and shared are necessary in revealing knowledge practices informing blended contexts.

The model further highlights frameworks supporting integrative knowledge building such a framework for transitioning across modalities, integration strategies, and professional development. A bidirectional relationship exists between transitioning across modalities and integration strategies. This relationship indicates that transitioning across modalities and integration strategies influence each other. As evidenced, findings on knowledge practices suggested that learner-centred practices which are more prominent in contact sessions can be adapted to online sessions to enhance learner participation in asynchronous settings.

Furthermore, effective transitions may require context-specific strategies such as rhetorical questions, conversational tone, macroscopic representations, analogies, familiar examples, diagrams, and real-world experiences as observed in lessons that were successful in building knowledge that is integrative. The subtle relationship represented by a dotted arrow from integration strategies to transitioning across modalities suggests that when integration strategies are explicit, teachers may be better equipped to seamlessly transition across modalities. This in turn strengthens or supports integrative knowledge building in blended contexts.

Furthermore, the relationship between integration strategies and professional development underscores the need for targeted teacher training to equip them with the skills necessary to implement necessary integrative knowledge building strategies. At the heart of this model, the teachers are considered an asset as they take on a role as knowledge builders. The blended learning pedagogical integration model (BLPIM) thus positions teachers as central in facilitating integrative knowledge building in blended contexts. Supported through professional development to successfully integrate specific strategies across modalities and successfully transition across modalities, effective integration of knowledge practices necessary for integrative knowledge building is possible. While learners contribute to knowledge building processes, the findings revealed that their participation is largely shaped by the pedagogical strategies opted for by the teacher. This reinforces the idea that without the teacher, integrative knowledge in blended contexts may be difficult to achieve. Furthermore, this reinforces the need for professional development programs that prepare teachers to navigate modality shifts, apply integration strategies, and cultivate enabling knowledge practices in blended contexts.

In response to the central question of this section, '*How can a model for integrative knowledge-building model through blended instruction and other supportive frameworks be developed*?' The simple answer is that the model can be developed by focusing on the autonomy pathways teachers adopt in their lessons, as these pathways make explicit the knowledge practices inherent in blended learning contexts. Additionally, a focus on strategic integration approaches for transitioning across modalities play a crucial role in this construction. Very key, the model enables integrative knowledge building by positioning the teacher as a knowledge builder, who is capable of making informed decisions about the knowledge structuring patterns, pathways and practices they adopt in their lessons.

5.7. Chapter summary

This chapter reported on the results and provided an analysis of all five secondary research questions to give insights of the main research question, “How does integrative knowledge building take place in contact and online sessions”? The chapter further used data insights from the four secondary research questions to construct a model of integration in blended learning contexts which takes into account processes and frameworks that support the integration. The next chapter provides a summary of the findings of the thesis and a discussion of what the findings mean in light of the existing literature.

CHAPTER 6: SUMMARY OF FINDINGS AND DISCUSSIONS

6.1. Introduction

This chapter presents a summary and discussion of the key findings in relation to the study's main and secondary research questions. The discussion is organised according to the sequence of the secondary research questions, from the first to the fifth, with the aim of building insight into the overarching research question: *How does integrative knowledge building take place in online and contact sessions?* Empirical findings are integrated with the literature to allow for a coherent interpretation and discussion of the data. Where common themes emerge across different questions, these are synthesised and discussed together to provide a more comprehensive understanding.

6.2. Secondary RQ1: Target knowledge for organic chemistry and teacher compliance

This question focused on understanding the target knowledge as prescribed in the Curriculum and Assessment Policy Statement (CAPS) for Technical Sciences Grade 12, focusing specifically on organic chemistry. It also aimed to understand how teachers comply with the curriculum documents. Understanding the target knowledge informs the knowledge structuring patterns and the autonomy pathways enacted during teaching and learning in both contact and online modalities.

The study found that teachers in both online and contact sessions complied with the CAPS-prescribed content for organic chemistry in grade 12. Across the observed lessons for both contact and online sessions, eleven core topics in organic chemistry were addressed in alignment with the curriculum expectations. This was further corroborated by teacher interviews, which revealed a shared understanding of curriculum expectations and a commitment to their implementation. This level of curriculum compliance suggests that teachers recognised CAPS as an authoritative guide in aligning lesson content accordingly. The SACE Professional Teaching Standards (PTSs) positions teachers as subject specialists arguing that teaching is fundamentally connected to teachers' understanding of the subject/s they teach (SACE final draft PTS for Gazette, 2018). For teachers to identify and focus on the target knowledge implies a foundational understanding of the subject matter. This finding affirms the central role of discipline-specific knowledge which is what Scardamalia and

Bereiter (2006) describe as “knowledge-in-development” within each subject area. Teachers are thus tasked with this responsibility of developing subject specific knowledge in the lessons they teach. Beyond complying with the curriculum, this finding shows how teachers positioned themselves within what LCT refers to as a knowledge code (Maton, 2014). By grounding their teaching in the CAPS curriculum (DBE,2011), teachers established targets that reflected their authoritative epistemic stance when teaching organic chemistry to grade 12 learners.

Being able to identify and focus on the curriculum knowledge allows the teachers to mould learners into experts of the science discipline. Clarence and Mckenna (2017) emphasises the importance of learners being aware of the concepts and skills they should possess when learning a subject. This further implies that before and along with integration of knowledge, teachers should be able to cultivate the knower gaze (Clarence & McKenna, 2017), clearly stipulating necessary domain concepts and skills that learners should possess within science classrooms. The professional teaching standards (SACE Final Draft, 2018) further underscore that teachers must not only know what to teach but also why and how to teach it to develop conceptual understanding among learners. All these dispositions combined speak to the need to first consult the curriculum documents to determine the requirements in terms of the content prescribed, which is what teachers in this study managed to do.

Another key finding is that lesson observations indicated the dominance of the sovereign code, where the focus was on target knowledge and purposes. This finding suggests that all teachers grounded their lessons in conceptual understandings of the science domain as prescribed through the curriculum to ensure that the disciplinary principles of organic chemistry were foregrounded. As VanScoy (2019) articulates, conceptual knowledge is the understanding of the underlying principles that govern a domain and the relationships among knowledge elements within that domain. When teachers emphasised conceptual understanding, they facilitated robust learning possibilities in a discipline like chemistry where abstraction and complexity are prominent (Molnár et al., 2023; Millar, 1991 & O’Dwyer and Childs, 2017). This reinforces the argument that conceptual knowledge is critical for meaningful knowledge acquisition in the sciences. As argued by Phanphech et al. (2019) conceptual knowledge and understanding are an important goal in learning generally, but particularly relevant in science education because such understanding is required to make sense of scientific phenomena. Through the identification and compliance to the curriculum documents, teachers ensured that they help learners understand the concepts required on the topic of organic chemistry thereby building knowledge of the discipline. Phanphech et al. (2019) highlights that conceptual understanding requires students to organise facts and ideas into meaningful concepts in science, which aligns with Mills' (2016) observation that students who develop conceptual understanding are less reliant on memorisation but instead engage in formulating ideas during learning. It is, however, important for teachers to remain committed to the prescribed content to ensure that learners acquire core disciplinary knowledge, while also being flexible enough to draw on other knowledge forms that support integrative knowledge building (Maton & Howard, 2018).

These findings collectively underscore that curriculum compliance when it reflects conceptual depth lays the groundwork for integrative knowledge building in science education. As noted by National Academic Press (2018), understanding of the domain knowledge is important to help learners recognise specific skills and knowledge in contexts and apply that knowledge in productive ways. This implies that integration of knowledge cannot occur unless teachers go beyond identifying target content to intentionally creating learning opportunities that weave together concepts across topics and disciplines. As Maton and Howard (2018) argue, integrative knowledge building requires recognition of the multiple forms that knowledge can take. Without clarity on what constitutes the core disciplinary knowledge, efforts at integration risk becoming superficial or misaligned. The second secondary research question thus reports on the finding's illustrating how the target concepts (aligned with the curriculum documents) identified by teachers is structured in contact and online sessions, revealing whether teachers were able to integrate other forms of knowledge or not to foster integrative knowledge building.

6.3. Secondary RQ2: Knowledge structuring patterns in contact and online sessions

This section presents the findings related to the second secondary research question: *What shift in knowledge structuring patterns are observed when teaching organic chemistry through contact and online sessions?* The findings are organised according to the extent of shifts noted in the lessons, the nature of autonomy codes that teachers tapped into overtime in their lessons, and the dynamics and conditions that shaped the observed shifts in these lessons. Rather than treating contact and online sessions separately, the findings and the discussion in this section explore both modes simultaneously to reveal cross cutting patterns of knowledge structuring patterns in both modalities.

One of the major findings revealed in this study is that the extent of the knowledge structuring patterns is shaped by the autonomy codes that teachers tapped into overtime in their lessons. This was reflected in the CT2 and OT1 lessons which demonstrated shifts across all four autonomy codes; sovereign, exotic, projected, and introjected. The shifts in the codes were repeated and purposeful shifts across all four codes as seen through the autonomy planes. As argued by Mathew (2012), teaching is purposeful interaction intended to promote learning as it involves teacher and learner engaging in joint purposeful activity. The observed shifts in these lessons enabled dynamic interactions between disciplinary content and other knowledge forms, thereby fostering interconnected learning experiences. This dynamic interplay resonates with the Community of Inquiry (CoI) framework's emphasis on the balance between cognitive, social, and teaching presences (Garrison, 2007). In CT2 and OT1, the cognitive presence was visible through conceptual progression, the teaching presence through the deliberate sequencing of content, and the social presence through collaborative reflection and discussion. However, while the CoI framework helps explain how presence supports engagement, it does not sufficiently account for the epistemic nature of the knowledge being constructed, nor the conditions under which different types of knowledge are integrated. This is where Legitimation Code Theory (LCT) adds explanatory depth, by showing how shifts in autonomy codes represent movements between disciplinary, every day and interdisciplinary forms of knowing. As argued by Maton and Howard (2020), knowledge is not just about acquiring facts but also about understanding its different dimensions and how it manifests in various contexts.

In both CT2 and OT1, teachers managed to weaken and strengthen positional and relational autonomy over time in their lessons thus, enabling learners to connect scientific knowledge with everyday experiences and knowledge from other domains. Such shifts align with the Complex Adaptive Blended Learning System (CABLS) framework (Wang et al., 2015), which emphasises the interdependence between teacher, learner, and technological subsystems. However, the CABLS tends to treat these relationships as structural rather than epistemic. My findings extend this model by demonstrating that integration in blended contexts is not only about system coordination but also about the quality of epistemic movement between forms of knowledge within those systems. In this way, the study contributes a finer-grained, knowledge-oriented understanding of how integration unfolds in practice.

The ability of the teachers to connect various knowledge forms reinforces conceptual understanding which requires students to organise facts and ideas into meaningful concepts (Phanphech et al., 2019) thus forming an understanding of how all pieces of information are linked together in a network (Rittle-Johnson & Schneider, 2015; Baroody et al., 2007; Miller & Hudson, 2007). These findings support Maton and Howard's (2018) assertion that the integration of diverse forms of knowledge is central to educational practice aimed at developing deeper conceptual understanding. Unlike much of the blended learning literature, which often isolates pedagogical or technological effectiveness (Hrastinski, 2019; Lalima & Dangwal, 2017), this study reveals that the pedagogical structuring of knowledge is equally important. It bridges the theoretical gap between knowledge integration (LCT) and system-level models (CABLS, CoI) by illustrating how teachers' pedagogical decisions transform blended instruction into sites for integrative knowledge building.

Maton and Howard (2018) further highlighted that the more shifts in autonomy codes observed in the lessons, the greater the opportunities for integrative knowledge building. As such CT2 and OT1 lessons were successful in expanding their knowledge base through the shifts observed as compared to other lessons. Integrative knowledge building is concerned with how knowledge from various sources can be brought together during instruction (Maton & Howard, 2020). It is important to note that the study also found that shifts in knowledge structuring patterns were largely informed by the selected pedagogical strategies in the lessons and more especially the role of learners and teachers in each context. According to Howard-Jones (2019) effective knowledge building involves reciprocal communication between the teacher and students, with the teacher playing a key role in guiding the construction of knowledge and reinforcing learning through activities such as application, practice, and reflection. This finding aligns with the Community of Inquiry (CoI) framework's assertion that iterative interaction fosters deeper learning (Garrison et al., 2000; Garrison, 2016). However, while CoI conceptualises this as an emergent community process (Garrison, 2007), the present study demonstrates that in high school blended science classrooms, such emergence depends on explicit guidance from the teacher which is a dimension often underemphasised in CoI research, which tends to assume a relatively self-directed learner population (Shea & Bidjerano, 2009; Vaughan et al., 2013).

Teachers in contact sessions by virtue of their contexts could engage learners in live interactive discussions (Špehte, 2021) whereas this was not possible in asynchronous sessions (Fadde & Vu, 2014). The CABLS framework acknowledges such contextual constraints but offers limited guidance on how epistemic quality can be maintained across these variations. The findings suggest that pedagogical intentionality, mediated through autonomy code shifts, is a critical mechanism through which teachers can preserve epistemic coherence when physical immediacy is lost. This insight strengthens CABLS by adding a layer of epistemic agency to its structural model. Moreover contextual factors highligted the advantages and disadvantages of both modalities in influencing knowledge structuring patterns. As Rigo and Mikuš, (2021) noted that a key limitation of asynchronous learning is the lack of personal engagement and opportunities for discussion and collaboration, while Fadde and Vu (2014) argue that asynchronous instruction offers fewer chances for the spontaneous interactions that naturally occur in contact sessions.

Teachers in asynchronous sessions had to devise alternative strategies, such reflective tasks, and scaffolded resources, to meaningfully incorporate learners into the teaching and learning process. This was evident in OT1, where the findings revealed innovative strategies that helped inform the shifts in knowledge structuring patterns of knowledge in the lesson. This insight highlights the need for teachers facilitating online lessons to possess technological knowledge that extends beyond basic tool usage as suggested by the SAMR model (Hamilton et al., 2016) to include the strategic integration of technology into pedagogical practices. As Laurillard (2012) notes, technological knowledge enables educators to design learning experiences that use digital tools not merely for delivery, but to actively support knowledge construction within lessons. Beyond equipping teachers with digital skills (Lalima & Dangwal, 2017; Rani et al., 2020; Teane, 2024; Garzon & Garzon, 2023) more should be done to link these skills with how content can be structured in these contexts to foster integrative knowledge building.

Even though lessons conducted through contact sessions may have contextual advantage (Ishtiaq et al., 2024; Lalima & Dangwal, 2017), the findings revealed that only CT2 among all the other lessons effectively incorporated knowledge from other sources. This suggests that knowledge of structuring patterns in blended contexts may depend less on modality and more on the teacher’s capacity to structure content in ways that are more meaningful. As much as the contextual role of teachers and learners played a significant role in shaping the knowledge structuring patterns, it is also important to note that these shifts were mostly facilitated by the ability of the teachers to organise content in ways that allowed for integration of knowledge from various sources. This highlights the significant role of the teacher in blended contexts as Lalima and Dangwal (2017) emphasised that the teacher remains at the centre of the learning process. The study, therefore, diverges from dominant blended learning discourse, which often privileges technological design or learner autonomy as the main drivers of integration. Instead, it highlights teachers' role as the central determinant of integrative learning.

This argument is further supported by an important comparative insight which revealed that both contact and online sessions managed to feature lessons with high, moderate, and low levels of shifts in knowledge structuring patterns. While context played a role in these shifts, the variation was however emphasised by how teachers enacted autonomy code shifts during the lessons, highlighting the significance of teachers' pedagogical strategies within specified contexts. For instance, CT2 (contact) and OT1 (online) both enabled strong integrative learning processes, while CT4 (contact) and OT3 (online) remained confined within sovereign codes and demonstrated no integration. This suggests that teachers' pedagogical decisions rather than contextual constraints are the most significant factor in shaping knowledge structuring patterns across modalities. Sharma (2019) asserts this view arguing that the teachers' role in blended learning has evolved to the extent that its implementation is not possible without their active involvement. This perspective stands in contrast to models such as CABLS (Wang et al., 2015) and the Community of Inquiry (Khan, 2022), which foreground the role of learners as the primary agents in facilitating learning within blended contexts.

In addition, it was found that all the lessons analysed were predominantly anchored in sovereign codes highlighting that knowledge was mostly aligned with target content and purposes. This was a necessary condition to equip learners with an explicit or implicit understanding of the principles that govern the science domain and of the interrelations between pieces of knowledge in the domain (VanScoy, 2019). However, lessons varied significantly in how they shifted away from these codes to incorporate other forms of knowledge. The focus on the sovereign codes reflects a dominant pedagogical logic that foregrounded technical sciences curriculum coverage with disciplinary knowledge focus at the expense of integration of knowledge. While sovereign codes as seen in CT1, CT3 and

OT3 help maintain the conceptual understanding of the knowledge of the science discipline, overstaying in this code hinders the ability for learners to view knowledge as interconnected networks (Walton and Ruszynyak 2019; Maton, 2009) thus limiting their ability to apply knowledge in other contexts (Mill, 2016). As noted by Maton (2013), such knowledge is segmented because it is so tightly bound to its context that it is only relevant within that context. Insights generated from the data, reveals a gap in international blended learning literature. For example, frameworks such as CoI and CABLS effectively describe structural and relational interactions, but they do not sufficiently theorise how curriculum-aligned disciplinary knowledge constrains or enables these interactions. This study contributes to closing this gap by integrating LCT's autonomy codes, thereby offering a tool for analysing knowledge shifts in blended settings.

Lessons that failed to shift across autonomy codes, most notably CT1, CT3, and OT3, offered limited or no opportunities for integrative knowledge building since shifts in knowledge structuring patterns were limited. As Maton and Howard (2018) argue, such segmented knowledge structures hinder the formation of integrative knowledge building and make it difficult for learners to meaningfully relate scientific content to the world beyond the classroom. Conceptual knowledge building requires students to develop, refine, and integrate deep, interconnected understanding of concepts rather than just accumulating facts relating to the knowledge of the domain (Phanphech et al., 2019). On the other hand, lessons such as OT4, OT2 and CT4 demonstrated moderate opportunities for integrative knowledge building by strategically incorporating exotic and projected codes alongside sovereign codes. These lessons featured shifts across two or three autonomy codes, allowing learners to engage with organic chemistry concepts while also making connections to everyday experiences and real-world applications. Although not as integrative as CT2 or OT1, these lessons show that even partial shifts can meaningfully expand the epistemic range of a lesson and open pathways for integration especially when teachers are deliberate in their knowledge structuring practices. This finding refines the CoI framework's "integration phase" by illustrating that integrative engagement in science learning is not merely social or dialogic but epistemically structured. In blended contexts, meaningful integration happens when teachers intentionally design pathways that allow learners to move fluidly between conceptual, applied, and contextual forms of knowledge.

To conclude, the findings revealed integrative knowledge building is possible in both contact and online environments but only when teachers demonstrate pedagogical reflexivity in how they structure knowledge while paying attention to contextual factors influencing the role of learners and their role as the teachers. This study thus complements and extends international models of blended learning. While CABLS and CoI provide robust frameworks for understanding systemic and relational dimensions of blended learning, they lack the epistemic granularity to account for how knowledge itself is built, legitimated, and integrated across modalities. Through the integration of LCT's autonomy dimension, this study contributes a pedagogical lens that illuminates how shifts in knowledge practices within lessons support or limit integrative knowledge building in blended contexts.

6.4. Secondary RQ3: The potential for autonomy pathways observed in contact and online sessions to promote integrative knowledge building

The analysis of autonomy pathways across both contact and online sessions revealed distinct patterns that significantly shaped the potential for integrative knowledge building in the organic chemistry lessons taught (Maton & Howard, 2020). Three key autonomy pathways were identified: stay pathways, return trips, and autonomy tours (dynamic and complete). According to Maton and Howard (2018) autonomy pathways are key features of integrative knowledge building as they help overcome issues of knowledge blindness, essentialism, and segmental models by identifying and analysing shifts in knowledge patterns over time. This process is essential for academic achievement (Maton & Howard, 2018), particularly in science education where complex and abstract concepts often require teachers to draw from diverse knowledge forms and procedures to support conceptual understanding. Conceptual knowledge and understanding are crucial goals in science education, as such understanding enables learners to make sense of scientific phenomena (Phanphech et al., 2019). However, achieving this understanding often requires teachers to go beyond the boundaries of disciplinary knowledge by drawing on diverse knowledge forms (Maton & Howard, 2018). Doing so ensures that learners can connect new knowledge to a broader network of organised disciplinary knowledge which is essential for meaningful learning. Therefore, in this study, the specific autonomy pathways identified provide important insights into how integrative knowledge building was either facilitated or constrained within both contact and online lessons.

The analysis of these pathways also reveals how integrative knowledge building can be understood through multiple theoretical lenses. While the autonomy pathways capture knowledge shifts within lessons (as per LCT), they also intersect with key elements of blended learning frameworks. For example, the patterns identified align with CABLS's notion of the interdependence among the learner, teacher, content, and technology (Wang et al., 2015) but extend this understanding by demonstrating that these relationships are not just functional but epistemic, shaped by the ways teachers mobilise and recontextualise knowledge forms over time. Similarly, the Community of Inquiry (CoI) framework (Garrison, 2007) explains how teaching, social, and cognitive presences interact to support deep learning. This study adds to that body of knowledge by showing that these presences materialise through specific autonomy shifts that connect disciplinary and contextual knowledge, thereby making visible the epistemic dimension that CoI tends to overlook.

Stay pathways, observed in CT1, CT3, and OT3, were characterised by teachers remaining within the sovereign code, focusing narrowly on understanding the concepts and procedures of the scientific discipline. Mills (2016) argues that science teaching should be focused on conceptual understanding to improve students' ability to reinforce connections and organise knowledge. Although stay pathways may be viewed as the home of conceptual understanding through shaping learners into the knowers of science and introduce them into the procedures of scientists (Clarence & Mckenna, 2017) they however limit opportunities for learners to consolidate knowledge or connect with wider contexts thus resulting to segmented learning (Walton & Ruszynyak, 2019; Maton, 2009). This means that learners may acquire organic chemistry facts but struggle to see how these concepts connect and apply in different contexts. In terms of blended learning theory, this finding reflects a limitation similar to what is seen in early interpretations of the SAMR model (Puentedura, 2020). In such cases, teaching often remains at the level of substitution or augmentation, where educators simply use technology to deliver existing content without transforming the epistemic relationships that underpin learning. The stay pathways observed in this study suggest that even in blended environments, without shifts across autonomy codes, learning remains constrained to traditional, teacher-directed delivery. Hence, these findings extend SAMR by showing that true transformation (the modification and redefinition stages) requires not only technological innovation but also epistemic shifts that link knowledge forms in meaningful ways.

Cooper et al. (2019) states that the topic of organic chemistry plays an imperative role in our daily lives while Chang and Goldsby (2016) add that the topic impacts modern science and technology. This implies that when teachers miss the opportunity to connect the topic with other forms of knowledge, it limits learners' ability to develop a holistic understanding of the topic and its real-world applications. This may lead to gaps in foundational knowledge, which can have a lasting negative impact on future STEM performance (Lopez et al., 2011). Knowledge is not just about acquiring facts or pieces of information from the domain but also about understanding different knowledge structures that may contribute to a comprehensive understanding of the subject matter. As argued by Parent et al. (2014), knowledge should be viewed as experiences; contextual understanding, value-added information, or insights derived from the cognitive frameworks of individuals or groups, which must be autonomously managed as it exists in many forms. In this study, stay pathways hindered the potential for integrative knowledge building, as knowledge remained constrained within the boundaries of the target content and procedures.

In contrast, return trips as seen in CT4, CT1, and OT2 involved teachers shifting between two autonomy codes. In the contact lessons, return trips extended knowledge to the projected codes, connecting the target content to mathematical knowledge (in CT1) or assessment purposes (in CT4). Although a return trip was observed in CT1, the lesson was primarily characterised by a stay pathway as the shift to the projected codes occurred only once and was brief. In contrast, OT2 extended knowledge to the exotic codes by linking target concepts with learners' everyday knowledge or experiences. Despite the differences in how these codes were enacted, all three return trips remained limited to two autonomy codes in the overall lessons. These limited shifts mirror the kind of "enhancement" described in the SAMR model and the "transitional" phase outlined in CABLS, where integration across systems occurs but lacks epistemic depth. While the partial movement between disciplinary and contextual knowledge forms offers some benefit, the absence of a sustained tours constrains the development of integrative knowledge building. This finding refines CABLS's broader view of adaptive systems by foregrounding epistemic adaptation as a critical dimension of teacher practice in blended contexts.

The ability of the teachers to expand the knowledge base ensured that learners understand the skills and knowledge necessary to conceptually understand the topic. As Clarence and Mckenna (2017) emphasises the importance of learners being aware of the types of knowledge and skills they should possess when learning a subject. Although return trips are simple tours reflecting the movement back and forth between two codes, they were, however, not sufficient for meaningful knowledge integration. Even so, Maton and Howard (2020) state that return trips provide better opportunities for integrative knowledge building as compared to stay pathways.

Autonomy tours emerged as the most promising pathway for fostering integrative knowledge building in both contact and online sessions. One of the most insightful findings of this study is the distinction and expansion of the autonomy pathway categories as originally conceptualised by Maton and Howard (2018). While their work categorised autonomy tours as a single type, this study introduces a further classification within this category, distinguishing dynamic tours from complete tours. Autonomy tours generally begin in one code, shift through one or more codes, and return to where they started (Maton & Howard, 2020). In this study, it was found that the dynamic tours, as observed in the CT2 and CT1 lessons, reflected teachers' ability to repeatedly shift between different autonomy codes over time in their lessons. These successive shifts signaled a complex and dynamic integration of knowledge explicitly highlighting how these teachers leveraged the opportunities offered by other knowledge sources to foster deeper understanding of the target content. This theoretical refinement extends the LCT literature by proposing that autonomy tours are not homogeneous but vary in their conceptual scope and pedagogical enactment. The distinction between dynamic and complete tours not only deepens the conceptualisation of autonomy pathways but also provides an analytic lens that can inform the design of blended learning pedagogies. This aligns with the CoI framework's emphasis on iterative cycles of reflection and discourse but extends it by revealing how these cycles operate in knowledge-building rather than merely communicative terms.

The evidence of dynamic and complete tours in these lessons provide insights into how teaching can become more meaningful when guided by intentional pedagogical strategies aimed at fostering integrative knowledge building across both online and contact contexts. This further highlights the teacher's role as a pedagogical expert in blended learning environments, as conceptualised in CABLS (Wang et al., 2015) and the Community of Inquiry (CoI) model for blended instruction (Khan, 2022). The CoI model emphasises teaching presence, which encompasses the design, organisation, and facilitation of learning experiences, as well as the selection of appropriate methodologies to enable meaningful learning (Becher Araujo Moraes, 2023; Zhang et al., 2020). Moreover, successful integrative knowledge building highlights the important relationship between the teacher, content, and pedagogy. This relationship is often underdeveloped in existing models. CABLS conceptualises this triad as a set of interconnected systems but does not articulate the epistemic processes through which teachers transform content for blended contexts. The findings in this study suggest that autonomy tours represent a practical enactment of this transformation, offering a framework for understanding how teachers' decisions move learning from procedural to integrative.

Interestingly, while both contact and online lessons demonstrated autonomy tours, the findings suggest that online lessons specifically OT1, OT4, and OT2 generally exhibited greater potential for integrative knowledge building compared to contact lessons. Among the highest-ranking lessons, three were online, with CT2 being the only exception from the contact sessions. This suggests that online learning environments offered greater flexibility, enabling teachers to draw from a wider range of knowledge sources and adopt strategies that fostered integrative knowledge building. This finding aligns with the adaptive potential outlined in CABLS but adds a crucial insight: flexibility in blended learning becomes meaningful only when it translates into deliberate movement across different forms of knowledge. This challenges assumptions within the CoI model that attribute depth of learning primarily to community interaction, proposing instead that integrative knowledge building is shaped by the teacher's capacity to design and facilitate meaningful knowledge engagement.

The affordances of asynchronous online learning such as access to multimedia resources and structured scaffolding (Hrastinski, 2008; Means et al., 2010) appear to support more deliberate pedagogical planning necessary for integrative knowledge building practices. For example, some contact lessons were constrained by rigid content delivery approaches which hindered the ability to shift across autonomy codes thereby resulting in stay pathways. While contact teaching allows for immediate interaction and spontaneous clarification (Špehte, 2021; Bušelić, 2012) the structured and resource rich nature of asynchronous environments better support integrative knowledge building practices. Thus, this study demonstrates that online teaching, when guided by critical reflection on knowledge, can transcend the limits of traditional pedagogical frameworks. It fosters conditions where knowledge integration becomes both intentional and visible which is an insight that contributes to the global discourse on effective blended learning design.

6.5. Secondary RQ4: Knowledge practices in blended learning environments that can promote integrative knowledge building effectively

To identify knowledge practices in blended environments that foster integrative knowledge building, this study examined both contact and online sessions, revealing a range of enabling and constraining practices as well as shared enabling practices across both modalities. The study found that enabling practices for integrative knowledge building in contact sessions included reflective and purposive teaching, interdisciplinary and contextual learning, and learner-centered approaches. In online sessions, the enabling practices comprised directional focus, assumed reflective practices, and included interdisciplinary and contextual learning similar to contact sessions. The findings suggest that while some enabling and constraining practices are mode-specific, others are shared across both environments (i.e. interdisciplinary and contextual learning), indicating a need for educators to adopt context-responsive strategies while intentionally adopting the implementation of enabling practices in blended instruction for integrative knowledge building to be a success.

These findings collectively advance theoretical understanding of how integrative knowledge building manifests in blended learning contexts. Existing models such as CABLS (Wang et al., 2015) and the Community of Inquiry (CoI) framework (Garrison, 2007) conceptualise the relationships between teacher, learner, content, and technology but do not always make visible the epistemic processes underpinning these interactions. The insights from this study extend these frameworks by showing that the effectiveness of blended learning lies not only in structural or technological alignment but in the knowledge practices teachers employ. In the context of this study, these include reflective, purposive, and contextualised pedagogies that facilitate movement across knowledge boundaries.

In contrast, passive learning, subject-centric focus, and risk-averse pedagogical practices in contact sessions constrained integrative knowledge building. Similarly, in online sessions, practices such as passive content consumption, content-saturated instruction, and subject-centric focus constrained integrative knowledge building. The constraining practices were predominantly observed in lessons characterised by stay and return pathways, which were identified as pathways offering limited opportunities for integrative knowledge building. Since the secondary research question guiding this discussion focuses on identifying practices in blended learning environments that effectively foster integrative knowledge building, this discussion will centre on the enabling practices identified across both modalities.

Similar but contextually distinct reflective practices were identified across both contact and online modalities and were found to be effective in fostering integrative knowledge building. While the underlying principle of reflection as a tool for pedagogical adjustment was shared across settings, the form and enactment of reflective practices varied according to the affordances and constraints of each modality. In contact sessions, reflective teaching practices refer to instances where teachers reflected in action through making real-time pedagogical adjustments based on immediate cues such as learners' facial expressions, verbal responses, or lack of engagement. For example, CT1 and CT2 demonstrated the ability to make reflective shifts by strengthening or weakening positional and relational autonomy based on learners' confusions noted through facial expressions, verbal cues, a lack of responses to posed questions. These adaptive pedagogical responses exemplify what Garrison (2007) describes as "teaching presence" in the CoI framework which describes the teacher's capacity to guide and reframe learning interactions in real time. However, this study advances the framework by demonstrating that reflective teaching does more than maintain instructional flow; it also triggers epistemic or knowledge shifts, allowing teachers to connect different knowledge forms dynamically during lessons. This reflective responsiveness represents a concrete enactment of epistemic agency, meaning that teachers actively shape how knowledge is constructed or transformed in the classroom. Through these micro-level decisions, teachers guide students' understanding and foster integrative learning in real time. This is a dimension that is often implied but not elaborated in the CoI model.

Through reflective shifts teachers were able to draw and reconcile targeted knowledge from a broader range of knowledge sources and in the process adapt instruction to support integrative knowledge building. This aligns with Mathew's (2012) conception of reflective practice as a practice involving deliberate thinking about actions that have already taken place and deliberate examination of classroom procedures, attitudes, and interactions. These findings further confirm the affordances of contact sessions as noted by Bao (2020) who argues that teaching requires significant teaching tools such as body language and facial expressions which allow learners to express themselves without the need for a dialogue. Based on these tools teachers would therefore reflect in action through actively evaluating thoughts, actions and practices opted for during instruction (Iqbal, 2017). In so doing deliberate and necessary shifts were observed highlighting intentional efforts in building knowledge that is integrative in their lessons. Viewed through the CABLS framework, this type of reflection illustrates the system's adaptive feedback loop, in which the teacher acts as a regulator balancing content, learners, and technology. This study, however, adds an important knowledge-focused perspective, showing that the teacher's adaptive actions are not only about managing the system but also about actively shaping and building knowledge, effectively reorganising the learning environment itself.

In contrast, reflective practices in online sessions were shaped by the absence of real-time learner feedback which is a condition that limits teachers' ability to respond effectively during instruction. According to Rigo and Mikuš, (2021), the primary disadvantage of asynchronous online learning is the lack of personal engagement and opportunities for discussion and collaboration with others. In such contexts, teachers engaged in what may be termed assumed reflective practices, where reflection was based on anticipating how learners might interpret or respond to content in the absence of direct interaction. Teachers prompted reflection through rhetorical questions or strategic prompts designed to activate learners' prior conceptions and encourage mental engagement with the material. This was evident in lessons such as OT1, OT2, and OT4, where rhetorical questioning created entry points into the target content and allowed for teachers to established necessary movements across knowledge domains.

These questions functioned similarly to what Cranton (2016) describes as content, process, and premise reflection questions, each serving to surface prior knowledge, examine the sources of learners' assumptions, and challenge core beliefs through reflective inquiry. For instance, rhetorical prompts in OT2 invited learners to engage with prior conceptions (content reflection), while questions in OT1 and OT4 encouraged learners to trace the reasoning behind their understanding (process and premise reflection). These practices reflect deliberate pedagogical strategies aimed at fostering critical reflection, which Cranton (2016) and Dirkx (2006) identify as central to building transformative knowledge. Despite limited interaction, such reflective strategies positioned learners to engage meaningfully with the content and supported teachers' efforts to enable knowledge that is integrative in online lessons. This anticipatory reflection aligns with the 'design-based teaching presence' dimension in the CoI model (Becher Araujo Moraes, 2023). However, the findings go further by showing that teachers use epistemic design not just technological tools to maintain engagement and support meaningful learning. By guiding cognitive presence through rhetorical prompts, teachers were able to offset the limited social interaction, showing that intentionally designed knowledge connections can sometimes take the place of immediate social presence.

Since learners engage with content independently in asynchronous sessions, it was necessary for teachers to anticipate potential responses and create necessary prompts to enhance learning. Doing so did not only enable integrative knowledge building but also strengthened key elements of the Community of Inquiry (CoI) model, particularly teacher presence and cognitive presence (Zhang et al., 2020). Cognitive presence, defined as the extent to which learners construct meaning through continuous reflection and dialogue, was evident in teachers' use of reflective prompts that encouraged learners to interrogate prior knowledge, question assumptions, and draw connections across knowledge domains. These moments of structured inquiry fostered the kind of sustained reflection that Zhang et al. (2020) identify as central to meaningful learning in online and blended environments. In addition, the teachers' actions also show how the higher stages of SAMR (modification and redefinition) can manifest in practice, not only through new technology but through deliberate restructuring of learning design. The reflective questioning strategies observed in OT1 and OT4 redefined the learning task from passive content consumption to knowledge building participation, illustrating how digital tools can support higher-order knowledge building when guided by deliberate teacher design.

At the same time, teaching presence which is understood as the design, promotion, and guidance of learners' cognitive processes and social communication was demonstrated through teachers' intentional structuring of asynchronous sessions, their use of rhetorical questioning, and the deliberate facilitation of reflective engagement. As Becher Araujo Moraes (2023) notes, effective teaching presence involves both curriculum design and discourse facilitation. In the observed lessons, teachers exhibited these elements by creating pedagogical structures that encouraged learners' cognitive engagement and simulated dialogic interaction, even in the absence of real-time feedback. The reflective strategies employed acted as markers of teaching presence by maintaining instructional direction and ensuring the teacher's guiding role was felt throughout the lesson. By embedding reflective practices that activate both cognitive and teaching presence, teachers were able to sustain learner engagement, guide knowledge construction, and facilitate autonomy shifts that support integrative knowledge building in asynchronous online contexts. In this way, the teacher's presence was not just symbolic but actively built into the lesson design, helping learners stay mentally engaged and connected to the knowledge and learning goals.

Thus, across both modalities, reflective practice served as a critical enabler of integrative knowledge building, though it manifested differently. In contact sessions, reflection was immediate and grounded in observable learner responses, whereas in online sessions it was anticipatory and structured through designed prompts. Nevertheless, in both contexts, reflection functioned as a dynamic process of adapting instruction, enhancing pedagogical responsiveness, and promoting deeper engagement with the content. As Babutta et al. (2024) emphasise, effective science teaching requires not only reflective thinking but also reflective action. When teachers engage in reflective inquiry, whether grounded in physical cues or cognitive anticipation they position themselves as reflective practitioners, continuously refining their instructional approaches in pursuit of meaningful integrated learning opportunities (Machost & Stains, 2023; Öztürk, 2021; Barber & Mourshed, 2009).

Purposive teaching in contact sessions was marked by deliberate shifts in autonomy codes aligned with specific instructional intentions. For example, all contact teachers remained within the sovereign codes when explaining concepts in relation to given class work activities or rectifying content knowledge. This indicates an intentional focus on disciplinary engagement so that the target content and purposes are achieved or maintained in the lessons. Additionally, teachers strategically employed scaffolding processes and activated learners' prior knowledge depending on the demands of the tasks. As Mathew (2012) argues, teaching is a purposeful interaction aimed at promoting learning, involving teachers and learners in a joint, goal-directed activity. In these lessons, the strategic use of teaching approaches that facilitated detailed explanations of the target content, drawing on both curricular knowledge and everyday understandings, played a central role in supporting integrative knowledge building.

These findings align with those of Gutiérrez-Braojos et al. (2024), who found that students valued teachers' explanations and scaffolding as essential tools for knowledge building. Such intentional pedagogical strategies contributed to shifts in autonomy codes, most notably in the CT2 lesson, where dynamic autonomy tours created greater opportunities for integrative knowledge building. At the same time, these purposive shifts align with the CABLS model's focus on systemic coherence, where teachers ensure that learning activities are aligned with curriculum objectives. This study, however, extends CABLS by showing that coherence is not only structural but also knowledge-focused: teachers preserve disciplinary consistency while intentionally creating opportunities for cross-domain connections that support integrative knowledge building.

The study found that interdisciplinary and contextual practices as observed in both modalities were effective in fostering integrative knowledge building. When teachers connected science concepts to learners' everyday experiences and other disciplines, learners were better able to see the relevance and interconnectedness of the content. This finding highlights a crucial theoretical bridge between LCT and blended learning models. While LCT provides a language for describing knowledge practices and movement of knowledge, frameworks like CoI and SAMR explain the socio-technical conditions that support such movement. The interdisciplinary practices observed in this study show that knowledge integration and technological integration reinforce each other, an insight that is often under-theorised in current blended learning models.

Grounding the lesson on these practices may help students build a deeper understanding by linking abstract scientific knowledge with familiar, real-world situations. Fostering interdisciplinary and contextual practices ensured that learners perceive curriculum knowledge as a set of interconnected ideas that relate to knowledge acquired from other domains and their everyday contexts. The CAPS document for Technical Sciences Grade 12 reinforces this view by emphasising that learners should demonstrate an understanding of the world as a set of related systems, recognizing that problem-solving contexts do not exist in isolation (DBE, 2014).

The teachers’ ability to integrate interdisciplinary and contextual practices supported integrative knowledge building by moving away from what Maton and Howard (2018) describe as segmented learning. In these lessons, target concepts were developed by building on existing knowledge, thus fostering integrative knowledge building (Walton & Rusznyak, 2019). While the teachers prioritised lesson goals related to understanding organic chemistry concepts, it is important to note that through both disciplinary and contextual engagements, they ensured that knowledge was not so tightly bound to its immediate context that it became relevant only within the framework of learning organic chemistry (Maton, 2013). This finding supports what is already known in the field of science education, particularly in the teaching of organic chemistry. Existing teaching methods highlight the importance of helping students connect theoretical content to practical, everyday contexts (Bhattacharyya & Bodner, 2018; Bodner & Elmas, 2020). The use of contextual practices in the observed lessons such as drawing on students' knowledge of other disciplines, using relatable analogies, and applying content to real-life examples created opportunities for learners to engage with content in a more meaningful way. This approach moved away from rote learning and promoted the kind of integrative understanding that allows learners to make sense of scientific ideas as part of a broader, interconnected system. This implies that students may be able to reason and comprehend concepts, operations, and relations between ideas that may be helpful in solving non-routine problems (Al- Mutawah et al., 2019).

Learner-centred approaches as identified in contact sessions played an important role in supporting integrative knowledge building. This was different from passive forms of learning, which limited opportunities for learners to build connections between ideas. In the CT1 and CT2 lessons, learners' questions and responses to the teachers' questions encouraged teachers to either weaken or strengthen positional and relational autonomy resulting in shifts in autonomy codes over time in the lessons. This underscores how teachers would adjust their teaching based on the learners and general instructional needs. This example is one of many highlighting how active learner participation can guide and improve the teaching process through cultivating knowledge in development of the discipline and of the context (Scardamalia & Bereiter, 2006).

As learners collaborate and negotiate for meaning using procedures and protocols of the discipline, they develop knowledge of the discipline (Scardamalia & Bereiter, 2006). For example, in these lessons learners or the teachers would ask questions involving drawing of structural formulas, with learners participating in drawing these formulas, identifying general formulas or rules for IUPAC naming and other procedures necessary to understand the topic of organic chemistry. This cultivated procedural knowledge which carries the characteristics of not only being an individual cognitive process but also a social one, occurring within interactive and collaborative spaces (Le at al., 2018; Ralston et al., 2017).

From a theoretical perspective, this finding adds depth to CABLS and CoI, both of which emphasise learner autonomy but often underplay the role of teacher guidance in shaping that autonomy where knowledge building os concerned. The shifts observed in CT1 and CT2 show that learner-centredness does not mean the absence of teacher control; rather, it involves the strategic structuring of learning space. This reconceptualisation contributes to global blended learning literature by clarifying how agency is co-constructed between teachers and learners.

As Saks et al (2021) and Gottlieb (2015) add, knowing how is a process that does not simple require learners to understand the concept but knowing how to use that knowledge to accomplish tasks, solve problems or follow systematic procedures within a particular domain. Through participation in the activities of the classroom learners were encouraged to cultivate their intellectual growth through actively participating not only in the receiving of the factual information of the target content but also in the active participation in the development of the knowledge (Scardamalia & Bereiter, 2006). Learners being active participants in the learning process became one of the factors helping teachers shifts between autonomy codes as they weakened and strengthened positional and relational autonomy based on these interactions. Scardamalia and Bereiter (2003) reinforces this idea by arguing that knowledge building is premised on the idea that each student is a legitimate contributor in the creation of authentic and creative knowledge.

In another example from CT2, learners answered a question incorrectly resulting in the teacher adjusting their teaching by weakening or strengthening autonomy to help learners understand the concept better. These shifts were based on how learners were relating to the content, and the teacher used their responses as a guide for how to proceed. The teacher also used learners' prior knowledge (elicited through questioning) to consolidate understanding thereby showing how learners' ideas can be used as a base for building deeper understanding. This supports what Paavola and Hakkarainen (2005) indicated that knowledge building values innovation of ideas and theories that arise through engagements from prior conceptions. Learner centred approaches fostered through strategies such as valuing learners' input, incorporating activities requiring learners to solve problems and eliciting prior knowledge fostered the development of integrative knowledge building. As argued by Hmelo-Silver and Barrows (2008) the kinds of questions asked, and the statements posed during instruction enable knowledge building discourse.

In addition, learners play an important role in assisting teachers to adopt practices that foster integrative knowledge building. For example, in the CT1 lesson, the teacher's focus shifted away from the content due to behavioural issues in the classroom. However, a learner's question helped bring the focus back to the main objectives of the lesson. This showed that learners can play a key role not just in keeping the lesson on track but in reinforcing knowledge building discourse. All these examples highlight the value of learner contributions during lessons as emphasised by the CABLS and Col models for blended instruction. Learner-centred teaching does more than involve students; it creates conditions where knowledge is built together, making learning more connected and meaningful. In STEM education, there is substantial evidence supporting the effectiveness of active learning in enhancing student engagement and understanding (Freeman et al., 2014; Arthurs & Kreager, 2017; Dou et al., 2018). Considering the difficulties and poor performance reported on the learning of organic chemistry, the study's findings that learner centred methods to teaching help build knowledge that is integrative is in line with strategies reported by several scholars in support of active learning strategies in organic chemistry (Abukar et al., 2023; Cooper et al., 2019; Deng & Flynn, 2021; Sabitu et al., 2020).

A distinctive finding in the online session data was the emergence of directional focus as a particularly effective strategy for enabling integrative knowledge building. While both modalities featured some form of directional prompting, its strategic use in online contexts stood out due to the demands of asynchronous instruction. As Špehte (2021) observes, online teaching requires educators to articulate their thoughts clearly to ensure that all learners can access and understand the instructional goals. In this study, teachers demonstrated this by explicitly stating lesson objectives and clearly outlining the rationale behind learning tasks through communicating both the *what* and the *why* of the lesson. This clarity played a critical role in initiating shifts across autonomy codes, especially in the absence of real-time interaction.

This approach further aligns with the CABLS model of blended learning, which describes the teacher's role as a “guide on the side” (Wang et al., 2015), supporting learners not through constant presence but by designing structured learning pathways that promote independent engagement. However, in the context of this study, the notion of guidance was far more complex. It involved helping learners not only access target content but also make connections that moved beyond disciplinary understandings. Through directional focus, a bridge was established that allowed learners to move between target and non-target knowledge domains. For example, in OT1 and OT4, teachers opened the lesson by explicitly stating the learning objectives, which functioned as an entry point into the lesson content. This initial move signaled stronger positional autonomy (PA) and relational autonomy (RA). However, as the lesson progressed, teachers deliberately and strategically weakened PA and/or RA by prompting learners to explore alternative perspectives, connect content to prior knowledge, or extend their thinking beyond the immediate task. These shifts were not random but carefully designed to foster integrative knowledge building.

In this way, directional focus in online settings acted as more than a navigational tool; it was a reflective pedagogical strategy that enabled learners to build meaning progressively guided by teacher-defined objectives, then encouraged to explore and integrate broader knowledge domains independently. This confirms the idea that effective online teaching is not merely about delivering content but about designing for epistemic engagement, especially when teacher presence must be enacted through design rather than real-time dialogue (Anderson et al., 2001; Garrison & Akyol, 2013).

The effective knowledge practices for integrative knowledge building in blended instruction are a synthesis of enabling practices observed across both contact and online settings. The findings on knowledge practices for integrative knowledge building in blended instruction have important implications for teachers' professional knowledge and pedagogical approaches. Firstly, the findings highlight the importance of teachers' understanding of their subject matter. For example, successful integrative knowledge building practices in blended instruction are grounded by a firm focus on discipline. This was evident as most of the pathways observed were dominated by sovereign codes. This means that integrative knowledge building practices identified as effective in blended contexts were largely influenced by the teachers’ ability to connect different forms of knowledge with knowledge of the discipline (target concepts).

In most cases knowledge from other domains or sources was primarily used to consolidate or expand understanding. This clearly highlights that the main knowledge domain necessary for integrative knowledge building to take place is knowledge of specific disciplines. As highlighted through the CABLS model (Wang et al., 2015) there is a clear relationship between the teacher and the content thus positioning the teacher as a knowledge specialist. This role is further reinforced by the South African Council for Education's professional teaching standards (SACE Final Draft PTs for Gazette, 2018), which recognize teaching as closely linked to teachers' understanding of the subject(s) they teach.

Furthermore, the emphasis on interdisciplinary and contextual learning practices suggests that teachers need a broad professional knowledge base that goes beyond subject-specific content. Such a knowledge base is necessary for them to draw meaningful connections across disciplines and real-world contexts. The technical sciences CAPS document for grade 12 reinforces this by emphasising the importance of learners demonstrating an awareness of the world as a set of related systems thus realising that problem-solving contexts do not exist in isolation (DBE, 2014). Without a broad understanding of knowledge and procedures from other domains, it is almost impossible for teachers to build knowledge that is integrative in their instruction. As previously mentioned, integrative knowledge building is concerned with how knowledge from various sources can be brought together during instruction (Maton & Howard, 2020).

Additionally, the emergence of reflective and learner-centred practices as effective knowledge building practices highlights the need for teachers to plan and reflect in action for integrative knowledge building to take place in blended contexts. For example, in both online and contact sessions teachers' reflective practices necessitated shifts in autonomy codes. Whereas in learner centered teaching, intentional prompts such as questioning were necessary to facilitate shifts. Both these practices highlight that if integrative knowledge building is the goal, then teachers ought to develop intentional reflective practices and strategies tailored to help learners engage with content.

From a general pedagogical point of view, the findings highlight the need for teachers in blended contexts to adapt their content and teaching strategies to allow for integrative knowledge building to take place. As noted in the lessons that fostered integrative knowledge building, teachers would intentionally or unintentionally venture out to other knowledge sources to help learners to understand the targeted content. Additionally, teachers would purposefully use rhetorical questions to engage learners and analogies to create familiar learning contexts. These outlined strategies contributed to practices such as reflective, learner centred and contextual learning.

In asynchronous online contexts, where interactions are generally limited (Fadde & Vu, 2014), it remains critical that teachers aim for integrative knowledge building in these contexts to master the art of how to teach using digital technologies. The "how' extends from the general understanding of simple recording a video but expands to teachers knowing how to use specific strategies such as a conversational tone and well formulated rhetorical questions that can stretch learners towards mental engagement. Moving beyond the basic use of technology to an understanding of the relationship between content, context, and technology is essential for integrative knowledge building. Doing so bridges the gap identified within the SAMR model for blended learning (Puentedura, 2020) which often reduces the teacher's role to technological pedagogical skills. The findings suggest that teachers should not only be competent in operating digital technologies, but they ought to understand how to structure and deliver content effectively in blended contexts. Furthermore, they need to adopt specific pedagogical practices that actively facilitate integrative knowledge building

From a practical point of view, the findings point out the need for ongoing professional development that can help teachers acquire the prerequisite knowledge and practices necessary for integrative knowledge building in blended contexts. As argued by Tan (2010), in order to turn schools into knowledge-building institutions, teachers must first become knowledge builders themselves. This requires intentional participation in the collaborative improvement of ideas related to the theories and practices of teaching and learning. In this regard, professional learning communities, workshops, and peer collaborations provide vital spaces where teachers can learn from one another, thereby expanding their knowledge base and refining pedagogical strategies.

DuFour et al. (2020) support this view, asserting that participation in professional learning communities where teachers observe colleagues' lessons, reflect on their practices, and engage in authentic professional dialogue can significantly enhance professional growth. Vokatis and Zhang (2016) further emphasise that being a knowledge builder is not just a skill but a professional identity, cultivated through iterative experimentation and improvement of teaching ideas over time. This identity, according to Barber and Mourshed (2009), is best developed through collaborative, data-driven, and practice-focused professional development. Additionally, Hartnell-Young (2003) points out that when teachers are given the space to reflect on current practices and access relevant tools and frameworks, they become more actively involved in shaping their roles. This is an essential condition for fostering integrative knowledge building in blended learning environments.

Together, these findings show that the effectiveness of blended learning cannot be explained by technology or delivery mode alone. Instead, it is the teachers' purposeful attention to knowledge that is demonstrated through practices such as reflective adjustments, guided scaffolding, and contextual connections. These determine whether blended learning fosters integrative knowledge building. This synthesis extends the CABLS, CoI, and SAMR models by offering an epistemic perspective on how teacher practices bring the systems and presences in these frameworks to life.

6.6. Secondary RQ5- Developing the blended learning integrative knowledge-building model

This section discusses the Blended Learning Pedagogical Integration Model (BLPIM) developed from the findings presented from the other four secondary research questions. The discussion situates the model within relevant theoretical frameworks, contrasts it with existing blended learning models, and interprets its implications for pedagogy, professional development, and educational practice. According to Miller and Salkind (2002) theoretical models consist of a set of assumptions about the specific concept under scrutiny. The blended learning integrative model is thus derived from a set of assumptions that are aimed at refining or introducing new perspectives to the existing blended learning models. Grounded in the interpretivist paradigm which sees reality as socially constructed and complex (Mustofa, 2023), the model acknowledges that such complexity influences how teaching and learning outcomes unfold in blended settings. Thus, at the heart of this model is the assumption that knowledge-building processes and frameworks must be made visible for teachers.

Unlike many existing frameworks that focus primarily on the structural or technological aspects of blended learning, the BLPIM foregrounds the epistemic and pedagogical dimensions of practice. It recognises that integrative knowledge building (IKB) is not a by-product of blended modalities, but an intentional and reflective process enacted by teachers as epistemic knowledge builders. In doing so, it offers a bridge between knowledge-building theory (Maton & Howard, 2020; Scardamalia & Bereiter, 2006) and blended learning frameworks such as CABLS and CoI, advancing a model that positions teachers not just as mediators but as constructors of knowledge systems within blended contexts.

While several scholars such as Van der Westhuizen and Hlatshwayo (2023), Mahlaba and Sekano (2023), and Singh et al. (2021) advocate for blended instruction, it is important to note that real transformation within the education landscape requires an evaluation and conscious contribution towards blended instruction pedagogical underpinnings. This evaluation should be holistic and position the teacher at the core of the instructional process. Likewise, Sharma (2019) reinforces this argument by stating that the success of blended instruction is impossible without teachers. A key limitation however is that current blended learning models relegate or narrow down this important role of the teacher by focusing on the role of learners and what technology can do in blended instruction. The BLPIM counters this by positioning the teacher as a knowledge builder who intentionally navigates content, pedagogy and context. Rusznyak et al. (2021) argue that teachers are better able to make informed decisions when pedagogical frameworks that support them are made visible. This resonates with the BLPIM's purpose of empowering teachers to engage in and reflect on knowledge structures and practices that foster integrative learning. The model thus redefines the "teacher presence" described in the CoI framework (Garrison & Vaughan, 2008), expanding it beyond facilitation and course design to include the active shaping of knowledge. It presents the teacher as both the designer and driver of knowledge integration, guiding how different forms of knowledge interact within and across learning modalities. This enhances CoI's understanding of teaching presence by linking it directly to explicit, knowledge-building processes.

The BLPIM responds to concerns that existing blended learning models inadequately reflect the multifaceted role of teacher. For example, in the CABLS model the learner is so crucial that the other components such as the teacher, technology, learning support, institution and the content are of secondary importance. Although this aims to enforce active participation in blended contexts (Wang et al., 2015), it remains notable that in so doing the role of the teacher is relegated. For example, the role of the teacher is reduced to facilitation, moderation, advising and guiding learners in relation to the content (Becher Araujo Moraes, 2023). The findings from this study contradicts this view highlighting that the teachers' role extends to knowledge building as they deliberately reflect on and refine practices to promote knowledge building during teaching and learning processes. The findings further suggest that the role of the teacher is not limited as it can take many forms clearly attributing to the complexities of teaching and learning (Joyce et al., 2009).

Although the content has a significant impact on both the subject matter and the methods used to engage learners in the learning process (Becher Araujo Moraes 2023), there is no clear indication of how teachers work with this content or the structures that underpin the practices related to delivering this content to learners. The BLPIM therefore contributes to addressing this gap by conceptualising teachers' engagement with content as an epistemic process that involves the navigation of autonomy codes, reflective practice, and knowledge integration strategies. This epistemic engagement is the core mechanism through which the model operationalises integrative knowledge building.

The Col framework on the other hand aims to provide adaptive, collaborative, and engaging learning experiences through both process and content. As such, the Col framework identifies instructional activities based on theory and practice to facilitate inquiry learning that is guided for learners (Cleveland-Innes, 2019). This grounds the model on inquiry -based learning while linking theory and practices (Garrison & Vaughan, 2008). However, the model does not explicitly outline the specific practices within blended contexts. In addition, this framework places emphasis on learners as active participants in the teaching processes, however, as the role of teachers keeps evolving in teaching and learning, this model may not be able to cope with the evolving dynamics of teaching and learning. Outlined from the key findings of this study, a variety of practices govern how teachers relate with the content, especially where integrative knowledge building is concerned. Furthermore, it is imperative that practices to be relayed in blended contexts are clearly outlined. Such an outline enables teachers to recognise the foundations of their decision-making practices, particularly when the underlying knowledge practices that inform these decisions are made explicit (Rusznyak et al., 2021). The BLPIM thus extends the CoI framework by articulating what these practices look like in contexts through identifying the knowledge building processes and frameworks such as, autonomy pathways, and strategies that teachers employ in real classroom contexts to move learners from disciplinary understanding to integrative knowledge building. In this way, it operationalises the abstract dimensions of cognitive and teaching presence into observable pedagogical actions.

Finally, the SAMR model grounds its focus on the use of new technologies in blended contexts (Nair & Chuan, 2021; Khan, 2022). However, as Blundell et al. (2022) argue, this model reduces teaching and learning to a product as it focuses on how technology is used rather than how teachers actively engage with knowledge in blended contexts. It is worth noting that through the SAMR model the role of the teacher is reduced to technological pedagogical skills which are necessary to enhance or transform learning in blended contexts (Teane 2024; Rani et al., 2020; Lalima & Dangwal, 2017) but alone insufficient to foster knowledge that is integrative. Teaching and learning are dynamic processes that cannot be reduced to what technology can help achieve. The SAMR does not explain how the technologies used connect to how teachers work with knowledge or the knowledge practices inherent when this model is adopted. The findings of this study revealed that there is a need for teachers to move beyond the basic use of technology to an understanding of the relationship between content, context and technology for integrative knowledge building to take place during instruction. The findings further suggests that science teachers should not only be competent in operating digital technologies, however, they ought to understand how to structure and deliver content effectively in blended contexts if the goal is integrative knowledge building. The BLPIM reconceptualises technology as a mediational tool that supports knowledge-focused activities, rather than as the primary driver of pedagogical transformation. In this framework, technological integration serves the purpose of enhancing learning and facilitating knowledge construction. It enables teachers to create new forms of access to knowledge, rather than merely digitising existing content. This perspective addresses a key theoretical gap in SAMR by defining transformation in terms of knowledge development rather than technology alone. The limitations from the existing models form a compelling rationale for the development of the BLPIM, which builds on these models while addressing their gaps by focusing on the centrality of teachers in enabling integrative learning. Drawing from these limitations, the BLPIM is guided by several key assumptions that shape its structure and purpose. These assumptions are not only pedagogical but epistemological — reflecting how knowledge is structured, accessed, and integrated across blended modalities. The first assumption is that effective integrative knowledge building requires a deep understanding and strategic use of distinct knowledge practices in both online and contact sessions. This implies that teachers must adopt context-specific practices that are responsive to the unique affordances of each modality (Garrison & Vaughan, 2008; Laurillard, 2012), while also leveraging integrative strategies that promote coherence across the blended learning environment (Hrastinski, 2019; Means et al., 2009).

Secondly, teachers who possess a deep understanding of content structures and the interconnections among concepts are better positioned to guide learners in integrating knowledge meaningfully. This is particularly true in complex topics such as organic chemistry (Salame et al., 2019), where conceptual coherence is essential for learners to make sense of abstract and highly interrelated ideas. As argued by the DBE (2014), teachers have a responsibility to support learners in viewing the world as an interconnected system, where problem-solving situations are linked rather than existing independently. As such for integrative knowledge building to occur, teachers must not only understand the target content but also its underlying knowledge structures and how they relate to broader scientific concepts. This is supported by the findings of the study, which revealed that lessons demonstrating dynamic and complete tours were more successful in extending knowledge to its broader dimensions. However, as reported by Adu-Gyamfi and Asaki (2022), many teachers themselves experience conceptual difficulties with organic chemistry. They argue that addressing these teacher difficulties is a more effective approach to improving students' understanding and performance in the subject. This highlights the urgent need for targeted professional development that supports teachers in mastering both the content and its conceptual relationships, thereby enabling them to foster integrative learning more effectively. The BLIPM responds to this need by carefully considering the need for professional development and positioning the teacher as a central agent in structuring of knowledge that is integrative for their learners.

Thirdly, the model emphasises the need to empower educators with explicit knowledge building practices to enhance pedagogy and learners' outcomes. When teachers understand the underlying structure of their instructional practices, they can more effectively justify and adapt their teaching strategies. This is supported by Rusznyak et al. (2021) and further reinforced by frameworks like Legitimation Code Theory (LCT), which provide teachers with tools to make informed decisions in their classrooms (Amundrud et al., 2020). In the same vein, Garraway and Reddy (2016) stress that teachers who are aware of knowledge structures are better able to guide students in connecting disparate ideas. Similarly, Maton and Howard (2018) argue that uncovering structural principles within practices while providing clear indications of the criteria through time is necessary to explore integrative knowledge building. This moves beyond the descriptive focus of earlier frameworks by offering teachers a generative tool. The framework not only describes what happens in blended contexts but helps teachers plan and justify their actions through an understanding of knowledge structures and autonomy shifts.

Expanding on these assumptions, the model argues that the teachers' role extends beyond facilitation, moderation, advising nor simply guiding learners in the learning processes (Becher Araujo Moraes, 2023). It also challenges the idea that teachers should primarily function as technology experts, as implied by models such as SAMR (Puentedura, 2020). Instead, the model recognises that teaching is a complex, complicated and multi-dimensional process (Jordan et al., 2014) that cannot be reduced to a limited set of functions. The model takes into account the broader professional, pedagogical, and relational responsibilities teachers hold in fostering meaningful and integrative knowledge building within blended learning contexts. Finally, the model assumes that ongoing professional development is necessary for educators to expand their knowledge base; that is both the knowledge of the discipline and set of related concepts from other disciplines and learners' experiences. As argued by Öztürk (2021) since teaching is a cognitive activity, it is important for teachers to understand and monitor the development of their teaching practices (Öztürk, 2021). Machost and Stains (2023) reinfoces this idea by stating that reflecting on practice continually improves teachers' efficacy and abilities. Through professional development, teachers can refine or be aided in developing pedagogical practices necessary for integrative knowledge building. The blended learning pedagogical integration model (PLPIM) thus reinforces that teachers are central to blended instruction especially if the educational goal is integrative knowledge building in science classrooms. The BLPIM thus positions teachers as central to blended instruction, particularly when the educational aim is integrative knowledge building in science classrooms. At the core of the model is the concept of the "teacher as knowledge builder", a professional who intentionally coordinates conceptual understanding, the learning context, and technological resources to support learner in integrating knowledge across topics and disciplines. This role highlights the teacher's active influence in shaping meaningful learning experiences and represents the principal contribution of the BLPIM to blended learning theory.

Following the model's assumptions, the BLPIM is thus framed around four major components, which emerge from the study's overall findings. First, autonomy pathways in blended instruction provide an understanding of the effective practices that support IKB (Maton & Howard, 2020). Second, explicit knowledge practices for blended instruction help identify the knowledge practices that enable IKB in both online and contact sessions. The model makes visible practices that can foster meaningful knowledge building during instruction. As argued by Rusznyak et al., (2021) such an outline provides teachers with the justifications for choosing specific practices in their teaching. Third, the framework for transitioning between modalities defines how shared enabling practices can be embedded to bridge the gap between contact and online instruction. This leverages the strengths of each mode (Papa, 2021), thereby providing a rounded approach to integrative knowledge building in blended contexts. Fourth, integration strategies highlight specific strategies that influence knowledge practices in blended contexts. All these components are underpinned by the model's emphasis on professional development for educators, recognising the need for ongoing development to ensure that teachers are equipped with the necessary knowledge, skills, and strategies for navigating complex blended learning environments (Barber & Mourshed, 2009; DuFour et al., 2020). Through professional learning communities and reflective practices, teachers can enhance their ability to foster IKB across diverse instructional modalities. In this respect, the BLPIM does not only provide a theoretical model but also a practical orientation for teacher professional growth. It enables teachers to analyse and improve their pedagogical reasoning, making it a model of reflective epistemic practice rather than static instructional design.

The BLPIM systems approach represents a structured but flexible framework that adds a new perspective for blended instruction. It provides a conceptual lens for science educators to critically reflect on their practices and improve their strategies for knowledge integration. While its design is grounded in empirical data, it remains a theoretical model, and as Taagepera (2008) cautions that such models may have limitations in capturing the broader landscape of blended instruction, particularly when considering variations across disciplines and specific topics. Even so, the BLPIM contributes a valuable perspective to ongoing conversations about blended learning by emphasising the importance of the role of teachers, pedagogical strategies, and the need professional development in achieving integrative knowledge building in science classrooms.

6.7. Chapter summary

This chapter presented the key findings related to the secondary research questions and discussed them in relation to existing literature to support a deeper understanding of the main research question, which explores how integrative knowledge building takes place in both contact and online sessions. The chapter concluded by highlighting the value of the Blended Learning Pedagogical Integration Model (BLPIM) as a guiding framework for science teachers. The BLPIM supports the development of integrative knowledge by making explicit the underlying processes and structures, and by demonstrating why such an approach is essential for effective science instruction across contact, online, and blended modalities. The next chapter concludes the thesis by summarising the key contributions, outlining practical and theoretical implications, and offering recommendations for future research.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1. Introduction

This chapter revisits the foundational argument presented in the introduction sections of the thesis. From the beginning it was argued that meaningful transformation in education particularly in embracing blended instruction in science education must begin with a critical evaluation of existing models. This evaluation should consider how these models can be enhanced to prioritise knowledge building as a core component of teachers' roles in these contexts (SACE Final Draft PTs for Gazette, 2018). At the heart of this thesis is the integral role of the teacher as a knowledge builder, supported by specific integrative knowledge building processes and structured frameworks. This role is reinforced through the blended learning pedagogical integration model, which highlights integration strategies and other supporting frameworks for science educators. Through the blended learning pedagogical integration model, teachers' integrative knowledge building practices in blended instruction were outlined and explained.

To guide this inquiry, the main aim of the study was to explore how integrative knowledge building takes place in lessons taught through contact and online sessions in the teaching of organic chemistry.

The specific objectives were to:

- Establish the target knowledge prescribed by the curriculum in the teaching of organic chemistry and establish whether teachers comply with these requirements.
- Identify shifts in knowledge structuring patterns when teaching organic chemistry through contact and online sessions.
- Examine how autonomy pathways in online and contact sessions promote integrative knowledge building.
- Explore the knowledge practices that enable teachers to facilitate integrative knowledge building in blended learning environments.
- Develop a blended learning model that can effectively guide teachers in integrating knowledge across modalities.

In addressing these objectives, the study generated a set of findings that contribute to new knowledge about the design and enactment of integrative knowledge building processes in blended science classrooms. These contributions are presented in three categories: theoretical contributions, empirical and practical implications for teaching, and contributions to the existing literature.

7.2. Contributions to new knowledge

Theoretical Contributions: The blended learning pedagogical integration model extends beyond widely used blended learning models such as SAMR, CoI, and CABLS as mentioned from the beginning of this thesis. The model emphasises knowledge practices in blended instruction, an aspect that is not explicitly addressed in these existing frameworks. The blended learning pedagogical integration model (PLBIM) highlights the pedagogical underpinnings necessary for blended instruction, particularly in science education. This is because of the argument that adopting blended learning as both a current and future teaching approach requires whole rounded frameworks that shed light on how teachers work with knowledge in these contexts. Unlike existing models which often prioritise use of technological as in the case of (SAMR) (Puentedura, 2020) and the role of learners (Col and CABLS) (Khan, 2022; Wang at al., 2015) in blended contexts. As previously mentioned, existing blended learning models do not fully capture how teachers actively work with knowledge, whereas the BLPIM model explicitly identifies knowledge building practices and instructional strategies that support IKB, making it a more teacher centred approach. While existing models emphasise the role of learners and technology, the BLPIM model ensures that the teacher's role and pedagogical expertise are equally considered in blended contexts. This shift theoretically balances knowledge in blended instruction by addressing both the learner's role in engaging with content (existing models) and the teacher's role in structuring and facilitating knowledge integration (BLPIM model) in science instruction.

By providing a systematic and structured approach, the blended learning pedagogical integration model (BLPIM) explicitly defines what is being taught (content knowledge) and how it is taught (knowledge-building practices that teachers adopt during instruction). Thus, revealing the relationship between content, pedagogy and context clearly highlighting strategies necessary to facilitate integrative knowledge building in blended contexts. The proposed model further underscores the teacher's role as a knowledge builder who facilitates meaningful learning through carefully structured knowledge practices. By doing so, the model enhances student learning outcomes ensuring that blended instruction is not just an integration of online and contact learning but an intentional knowledge building platform.

Practical and empirical contributions: Although the focus of the study is blended instruction, the BLPIM model acknowledges both contact and online sessions as distinct yet interconnected. This model design allows for flexibility in terms of implementation. For example, the dual approach ensures that the model can be applied by educators working in either contact or online modes as well as those blending the two modes. Through identifying enabling knowledge practices in these contexts, the study provides a structured guide for science educators to make informed pedagogical decisions about their instruction. In other words, the BLPIM model aims to aid science educators to refine their practices and adopt strategies that enhance integrative knowledge building.

Furthermore, even though the study focuses on secondary school level the model is not limited to this context. The model may be adaptable to other levels such as higher education and primary school. This offers a scalable framework that can be adjusted based on institutional and subject needs. The study bridges the gap between theory and practice by providing empirical evidence on how science teachers work with knowledge from a structured pedagogical point of view. This further reinforces the need for targeted professional development through workshops, learning communities, and mentorship programs.

Literature contributions: This thesis makes a significant contribution to the literature on blended instruction. This literature extends beyond the traditional focus on implementation as the focus is both on the 'what' and 'how'. In this case educators are intentional about how they work with knowledge. Much of the existing literature emphasises access, infrastructure, the digital divide, teacher and learner training, digital skills, and strategies to enhance engagement and motivation (i.e. Singh et al., 2021; Mmakola & Maphalala, 2023; Jeffrey et al., 2014; Jantjies, 2020; Sharma, 2019), these aspects primarily address practical challenges in blended instruction.

The focus on the above-mentioned aspects may improve accessibility to knowledge but does not necessarily develop a holistic understanding of the pedagogical foundations that underpin how science teachers may work with knowledge or integration of knowledge in blended contexts. This study bridges that gap by shifting the focus to knowledge-building processes within blended instruction. The study enhances our understanding of the complex nature of teaching by focusing on how science teachers engage with knowledge, the knowledge practices they adopt, and how different forms of knowledge are structured and integrated in blended environments. This complexity is often overlooked in the broader discourse on blended instruction since recommendations tend to focus primarily on aspects that may improve access rather than the pedagogical underpinnings that shape effective instruction in these contexts.

7.3. Limitations of the study

Although the blended learning pedagogical integration model (BLPIM) may be adaptable across different subjects and educational levels. It is important to acknowledge that the findings that emerged in the study may be influenced by specific subject disciplines. Given that the findings of the study were based on exploring the topic of organic chemistry in technical sciences for grade 12, it means that the findings cannot be generalised and the application of the model to other subjects and other topics in technical sciences may require careful consideration. Since disciplinary knowledge structures vary significantly across domains, specialists adopting the model must be mindful of the unique pedagogical strategies and disciplinary knowledge structures that shape their own instructional choices. Furthermore, the study was done with only eight participants located in one district and one province, whereas the generalised findings could imply many schools offering the subject. Additionally, while the model emphasises the teacher's role in knowledge building it does not extensively address the learner's contribution to effective knowledge building practices in blended contexts. This creates a potential imbalance in embracing the reciprocal nature of teaching and learning where integrative knowledge building is concerned. Although the findings indicate that that learners' contribution to integrative knowledge-building practices is influenced by teachers' strategies, the model does not explicitly explore how learners can independently influence the knowledge practices observed.

7.4. Implications

The findings of this thesis have significant implications for policy, curriculum development, and classroom practice. Through an understanding the specific knowledge practices, policymakers, curriculum developers, and institutional leaders can design blended learning frameworks that effectively integrate knowledge-building strategies into both curricula and teacher training programs. Moreover, an explicit understanding of knowledge practices and integration strategies in blended contexts places the teachers in a position where they can make informed decisions relating to how each practice can be modified or leveraged to suit specific needs in blended contexts. Doing so will enable a community of educators to adopt common frameworks that are useful within specific contexts.

From a practical perspective, the findings highlight the need for ongoing professional development programs. These programs are aimed at equipping teachers with the necessary knowledge and skills for integrative knowledge building. To support this, the study recommends intentional establishing of professional learning communities, workshops, and peer collaboration networks. These initiatives should be grounded in the beliefs that teachers can learn significantly from each other through sharing knowledge about their own practices and teachers can be empowered to refine their pedagogical strategies and expand their knowledge base, thereby fostering a deeper commitment to integrative knowledge building in their classrooms.

7.5. Recommendations for future research

Future research can be explored in the followings areas to counteract some of the identified limitations, improve and support the implementation of the model.

1. Conducting longitudinal studies would help measure the effectiveness, adaptability, and general integration of knowledge-building practices across different subjects and levels. By tracking how teachers use the model overtime, researchers can assess how well the model supports sustainable knowledge building in blended instruction. Doing so would allow researchers to identify any adjustments needed for long-term implementation.
2. While the current study primarily focuses on the teacher's role as a knowledge builder, further research could examine the learner's active role in shaping knowledge practices. Investigating how learners contribute to and influence integrative knowledge building within blended learning environments can help balance the teacher-learner dynamic in future versions of the model.
3. Future studies could empirically test how the model performs across different disciplines to determine whether certain knowledge practices are universally

applicable or subject dependent. This would refine the model by incorporating discipline-specific teaching strategies while maintaining its core principles.

4. Future research can be done to investigate how professional development interventions impact teachers' ability to implement integrative knowledge building strategies. This would help refine the model's practical application.
5. The model's adaptability in various learning environments such as primary school and higher education could be tested to refine its scalability and contextual relevance.

7.6. Conclusion

Meaningful transformation in science education requires more than general recommendations for blended instruction; it demands clear frameworks that outline actionable steps that go beyond implementation in blended contexts. This study brings together all key discussions and argues that these steps must prioritise pedagogy, content, and context, ensuring that teachers are equipped with the necessary knowledge to effectively inform and guide their practice. Recommendations for blended instruction alone are insufficient without tangible evidence of how teachers should work with knowledge in these contexts. This thesis contributes significantly to the discourse on how teachers can effectively connect pedagogy, content, and context in blended learning environments. This study concludes that knowledge without a clear framework for its application is incomplete. The proposed Blended Learning Pedagogical Integration Model (BLPIM) thus offer a structured system that provides a practical guide for science teachers, enabling them to seamlessly integrate knowledge while addressing both issues of context and pedagogy. This model offers more than just guidance; it provides a practical and pedagogically sound pathway for advancing knowledge integration in blended learning by paving the way for more meaningful and effective teaching practices.

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APPENDICES

Appendix A: Ethical clearance

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Duma

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H22/05/08**
PROJECT TITLE	Integrative knowledge building in distance and contact sessions: An exploratory study of mechanics lessons in Technical Sciences for grade 12
INVESTIGATOR(S)	Ms A Duma
SCHOOL/DEPARTMENT	Wits School of Education/
DATE CONSIDERED	22 May 2022
DECISION OF THE COMMITTEE	Approved Risk Level: Minimal
EXPIRY DATE	16 October 2025

DATE 27 January 2023 **CHAIRPERSON** ______________________
(Professor J Watermeyer)

cc: Supervisor : Prof E Mushayikwa and Prof M Stephen

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **A SIGNED COPY** returned to the Secretary electronically. Unreported changes to the application may invalidate the clearance given by the HREC (Non-Medical)

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure be contemplated from the research procedure as approved I/we undertake to submit an amendment of the protocol to the Committee. **I/we agree to completion of a regular progress report. For Minimal and Low Risk studies, this is due annually on 31 December. For Medium and High Risk studies, this is due twice annually on 30 June and 31 December.**

______________________ 31 / 01 / 2023
Signature **Date**

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Appendix B: Gauteng Department of Education ethics clearance

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE RESEARCH APPROVAL LETTER

Date:	**26 January 2023**
Validity of Research Approval:	**08 February 2023– 30 September 2023** **2022/458A**
Name of Researcher:	**Duma A**
Address of Researcher:	**136 Pritchard Street**
	Johanneburg
Telephone Number:	**011 71773089 / 074 609 1942**
Email address:	**1143754@students.wits.ac.za**
Research Topic:	**Integrative knowledge building in distance and contact sessions: An exploratory study of mechanics lessons in Technical Sciences fro Grade 12**
Type of qualification	**PhD**
Number and type of schools:	**12 Secodnary Schools**
District/s/HO	**15 Districts**

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

26/01/2023

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below are met. Approval may be withdrawn should any of the conditions listed below be flouted:

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *The letter would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. ***Because of the relaxation of COVID 19 regulations researchers can collect data online, telephonically, physically access schools, or may make arrangements for Zoom with the school Principal. Requests for such arrangements should be submitted to the GDE Education Research and Knowledge Management directorate.***
4. ***The Researchers are advised to wear a mask at all times, Social distance at all times, Provide a vaccination certificate or negative COVID-19 test, not older than 72 hours, and Sanitise frequently.***
5. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s has been granted permission from the Gauteng Department of Education to conduct the research study.*
6. *A letter/document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs, and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
7. *The Researcher will make every effort to obtain the goodwill and cooperation of all the GDE officials, principals, and chairpersons of the SGBs, teachers, and learners involved. Persons who offer their cooperation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
8. *Research may only be conducted after school hours so that the normal school program is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
9. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
10. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
11. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
12. *The researcher is responsible for supplying and utilising his/her research resources, such as stationery, photocopies, transport, faxes, and telephones, and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
13. *The names of the GDE officials, schools, principals, parents, teachers, and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
14. *On completion of the study, the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
15. *The researcher may be expected to provide short presentations on the purpose, findings, and recommendations of his/her research to both GDE officials and the schools concerned.*
16. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a summary of the purpose, findings, and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

....

Dr. Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: ....26|01|2023....................

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

Appendix C: Consent forms

(i) Principals' request letter

Dear Sir/Madam,

<u>Re: Request for permission to conduct a research study at your school</u>

My name is Angeline Duma. I am a PhD student in the Wits School of Education at the University of the Witwatersrand. I am writing to request permission to conduct a research study at your school. GDE approval has already been granted. The research is titled: **Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for grade 12.**

The main purpose of the study is to explore how integrative knowledge building takes place in lessons taught through distance and contact sessions. My research involves the following data collection methods: direct observations (conducted by the researcher, **Angeline Duma**), pre-recorded video observations (requested from the **Technical Science** teachers who volunteer to pre-record rather than be observed), video recording of the lessons taught by the teachers and audio recording of semi structured interviews with the teachers.

The audio/video recordings of the lesson observations and semi-structured interviews will be transcribed verbatim and analysed to answer the research questions of this study. Video/audio recording is necessary to provide data that I can observe several times to facilitate in depth - analysis of the lesson observations and interviews.

The study will be conducted during school hours (lesson observation only) and after normal school hours (interviews with the teachers). The interviews will take approximately 20 minutes of the teachers' time and will be done at their convenience. I am inviting your school to participate in this research voluntarily and your school will not be disadvantaged or penalised for not participating. You are also free to withdraw your school from participating in the study at any stage. The participants will be reassured that they can withdraw their permission at any stage during the study without penalty. There are no foreseeable risks in participating in this study. The participants will not lose any services, benefits or rights they would normally have if they decide not to join. Taking part in the research study is voluntary and participants will not be paid for participating in this study.

The names of the research participants and identity of your school will be kept confidential at all times. Individual privacy will be maintained in all published and written data resulting from the study. Pseudonyms will be used to identify the participants in all academic writings arising from this study to maintain anonymity and confidentiality. The results will be communicated through a research report and academic journals as required for the fulfillment of the degree. All research data will be securely stored in a password-protected computer and the data will be destroyed 5 years after the study is completed.

Your approval to conduct this research will be greatly appreciated. If you agree, kindly sign the following consent form. Please let me know if you require any further information. **If you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon- <u>medical@wits.ac.za</u>.**

Yours sincerely,
Angeline Duma

(ii) The principal consent form

I, ………………the principal of …………………………School give my written consent to Miss Angeline Duma to conduct her research study titled: **Integrative knowledge building in distance and contact sessions: An exploratory study of mechanic lessons in Technical Sciences for grade 12** in my school.

I understand that the study involves the following data collection methods: direct observations, pre-recorded video observations, video recording of the lessons taught by the teachers and audio recording of semi structured interviews with the teachers. I understand and agree that the study can be conducted during school hours (observations only) and after normal school hours (interviews).

I understand that confidentiality and anonymity of my school, teachers and learners will be maintained in all publications and all written data resulting from the study. I understand that pseudonyms will be used to identify the participants in all academic writings arising from this study to maintain anonymity and confidentiality. I also understand that participation of my school in this research study is voluntary, and I can withdraw my school from the study at any stage without penalty. I understand that the participants will not lose any services, benefits or rights they would normally have if they decide not to join. I agree that participants will not be paid for participating in this study.

I understand that the data collected from my school will be used for educational purposes as required for the fulfillment of the degree of the researcher. I understand that all research data will be securely stored in a password-protected computer and the data will be destroyed 5 years after the study is completed.

Date: …………………………………………….

Signature: ……………………………………..

<u>SCHOOL STAMP</u>

(iii) Participant information sheet (PIS) - Parents

Dear Sir / Madam

My name is Angeline Duma; I am PhD student at the University of the Witwatersrand, Johannesburg. My supervisors are Dr Emmanuel Mushayikwa and Dr Magdeline Stephen. I am conducting a research study that focuses on exploring how technical science teachers build knowledge in distance and contact sessions on the topic of organic chemistry for grade 12 learners. The main purpose of the study is to explore how integrative knowledge building takes place in lessons taught through distance and contact sessions. The study title is: **Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for grade 12.**

I am asking for your permission to include your child in my research study. The study will deploy the following data collection methods: direct observations, pre-recorded observations and interviews from the teachers. In direct observations I will sit in a class and observe teachers as they teach while in pre-recorded observations, I will request teachers to record a session teaching the topic of organic chemistry, this recording will later be observed and analysed.

The direct observations will take place at the school where your child is enrolled during the scheduled time as per the school timetable while the pre-recorded videos will be accessed from the respective teachers who teach your child. The data collected for this research will be securely stored in a password-protected computer to ensure that access is only granted to the researcher. The data obtained in this study will be destroyed after 5 years upon completion of the study. Only the researcher (Angeline Duma) will have access to the data.

The data collected from observations will be confidential and anonymous. When I share the results of the research study, I will not include your child's name or anything else that could identify them. Participation is voluntary and refusal to participate will involve no penalty or loss of benefits to which your child is otherwise entitled. If you decide to allow your child to take part in this study, you need to know that they can stop being in the study at any time. Taking part in this research study is voluntary; learners will not be paid for their participation.

The risks for this research study are no more than what happens in everyday life. This research study will be written up as a research report and research publications required for my level of study. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you as soon as it is available. If you have any questions during or afterwards about this research study, feel free to contact me or my supervisors. In addition, if you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon- medical@wits.ac.za.

Yours Sincerely,

Angeline Duma

(iv) Participant information sheet (PIS) -Teachers

Dear Sir / Madam

My name is Angeline Duma; I am PhD student at the University of the Witwatersrand, Johannesburg. My supervisors are Dr Emmanuel Mushayikwa and Dr Magdeline Stephen. I am conducting a research study that focuses on exploring how technical science teachers build knowledge in distance and contact sessions on the topic of organic chemistry for grade 12 learners. The main purpose of the study is to explore how integrative knowledge building takes place in lessons taught through distance and contact sessions. The title of the study is: **Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for grade 12.**

I am inviting you to take part in my study by allowing me to observe your lesson as you teach the topic of organic chemistry to grade 12 learners. The study will deploy the following data collection methods: direct observation, pre-recorded observations and semi-structured interviews. In direct observations I will sit in your class and observe as you teach while in pre-recorded observations, I will request that you record a session teaching the topic of organic chemistry, this recording will later be observed and analysed. Based on the proceedings of the research study, you may be asked to volunteer to be observed or to record a lesson in which you teach organic chemistry to grade 12 learners. To understand the dynamics that shape your practices during your lesson, I will request to have an interview with you. The interview will take approximately 20 minutes of your time and can be done at your convenient time.

One observation of your lesson where you teach the topic of organic chemistry to grade 12 learners will be made. The observations will take place at your respective school during the scheduled time for your periods as per the school timetable. If you decide to volunteer to pre-record the lesson, one pre-recorded video recording will be appreciated.

With your permission, I would like to video record your lessons so that I can be able to analyse the lesson with greater detail focusing specifically on instances where knowledge building is occurring during the lessons. In addition, I would like to request to audio record our interview session.

If you are one of the teachers who volunteer to pre-record the lesson, I would like to analyse your pre-recorded video with your permission. The data collected for this research will be securely stored in a password-protected computer to ensure that access is only granted to the researcher. The data obtained in this study will be destroyed after 5 years upon completion of the study. Only the researcher (Angeline Duma) will have access to the data.

The data collected from observations will be confidential and anonymous. When I share the results of the research study, I will not include your name or anything else that could identify you. If you decide to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. You will not get any direct benefits if you choose to join the research study. You will not lose any services, benefits or rights you would normally have if you decide not to join. Taking part in the research study will not cost you anything. You will not be paid for being in this research study.

The risks for this research study are no more than what happens in everyday life. This research study will be written up as a research report and research publications required for my level of study. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you as soon as it is available. If you have any questions during or afterwards about this research study, feel free to contact me or my supervisors. In addition, if you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon- medical@wits.ac.za.

Yours Sincerely,

Angeline Duma

(v) Participant information sheet (PIS) -Learners

Dear Learner

My name is Angeline Duma; I am PhD student at the University of the Witwatersrand, Johannesburg. My supervisors are Dr Emmanuel Mushayikwa and Dr Magdeline Stephen. I am conducting a research study that focuses on exploring how technical science teachers build knowledge in distance and contact sessions on the topic of organic chemistry for grade 12 learners. The main purpose of the study is to explore how integrative knowledge building takes place in lessons taught through distance and contact sessions. The study title is: **Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for grade 12.**

The following data collection methods will be used in the study: direct observations, pre-recorded observations and interviews. In direct observations, I will sit in your class and observe your teacher as she/he teaches, whereas in pre-recorded observations, I will ask your teacher to record a session teaching the topic of organic chemistry, which will then be observed and analysed. Although I am observing your teacher teaching the topic of organic chemistry any comments or interactions that you may during the lesson may potentially be used as data in my study.

The observations will take place at your respective school during the scheduled time for your periods as per the school timetable. The data collected for this research will be securely stored in a password-protected computer to ensure that access is only granted to the researcher. The data obtained in this study will be destroyed after 5 years upon completion of the study. Only the researcher (Angeline Duma) will have access to the data.

The data collected from observations will be confidential and anonymous. When I share the results of the research study, I will not include your name or anything else that could identify you. If you decide to take part in the research study, it should be because you want to volunteer. You do not have to take part. You can stop being in the study at any time. You do not have to answer any questions if you do not want to. You will not get any direct benefits if you choose to join the research study. You will not lose any services, benefits or rights you would normally have if you decide not to join. Taking part in the research study will not cost you anything. You will not be paid for being in this research study.

The risks for this research study are no more than what happens in everyday life. This research study will be written up as a research report and research publications required for my level of study. The report will be available on the university library website. If you would like to receive a summary of this report, I will be happy to send it to you as soon as it is available. If you have any questions during or afterwards about this research study, feel free to contact me or my supervisors. In addition, if you have any concerns or complaints about the ethical procedures of this research study, you are welcome to contact the University Human Research Ethics Committee (Non-Medical), telephone +27(0) 11 717 1408, email hrecnon- medical@wits.ac.za.

Yours Sincerely,

Angeline Duma

(vi) Consent form -Parents

Title of project: Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for grade 12.

Name of researcher: Angeline Duma

I, ……………………………………………………………………. allows my child (Name of child) ……………………….… to participate in this research project.

I agree to the following: (Please circle the relevant options below)

1. The research study was explained to me. I understand what this study is about.	YES	NO
2. I am allowing my child to be part of the study.	YES	NO
3. I understand that my child can volunteer to take part in the study.	YES	NO
4. I understand that my child will not be paid for their participation.	YES	NO
5. I agree that my child will be observed, and video recorded.	YES	NO
6. I agree that direct quotations from the observation transcripts may be used by the researcher in their research report.	YES	NO
7. I agree that my child's participation will remain anonymous (their name will not be used by the researcher in their research report)	YES	NO
8. I understand the risks involved in the study.	YES	NO

Please **print your name and sign** below

Name and surname: ………………………………………
Date: ……………………………………………………
Signature: …………………………………………………

Name of researcher: ……………………………………...
Date: …………………...
Signature: ……………………………………………….

(vii) Assent form -Learners

Title of project: Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for grade 12.

Name of researcher: Angeline Duma

I, ……………………………………………….agree to participate in this research project.

I agree to the following: (Please circle the relevant options below)

1. The research study was explained to me.	YES	NO
2. I understand what the study is about.	YES	NO
3. I understand that my participation is by virtue of being in the class where the researcher is observing my teacher.	YES	NO
4. I agree to take part in this study.	YES	NO
5. I agree that I will be observed, and video recorded.	YES	NO
6. I understand that my participation will remain anonymous (my name will not be used by the researcher in their research report).	YES	NO
7. I understand that I will not be paid for my contribution in this study.	YES	NO
8. I understand that I can stop being part of the study at any time.	YES	NO
9. I understand the risks involved in the study.	YES	NO

Please **print your name and sign** below

Name and surname: ………………………………………
Date: ………………………………………………………
Signature: …………………………………………………

Name of researcher: ……………………………………..
Date: ………………..
Signature: ……………………………………………….

(viii) Consent form –Contact Teachers

Title of project: Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for grade 12.

Name of researcher: Angeline Duma

I, ………………………………………………..agree to participate in this research project.

I agree to the following: (Please circle the relevant options below)

1. The research study was explained to me.	YES	NO
2. I understand what the study is about.	YES	NO
3. I agree / volunteer to take part in this study.	YES	NO
4. I agree that I will be observed, and video recorded.	YES	NO
5. I agree that I will be interviewed, and audio recorded.	YES	NO
6. I agree that direct quotations from the observation transcripts may be used by the researcher in their research report.	YES	NO
7. I understand that my participation will remain anonymous (my name will not be used by the researcher in their research report).	YES	NO
8. I understand that I will not be paid for my participation in this study.	YES	NO
9. I understand that I can stop being part of the study at any time.	YES	NO
10. I understand the risks involved in the study.	YES	NO

Please **print your name and sign** below

Name and surname: ………………………………………

Date: ……………………………………………………

Signature: ………………………………………………

Name of researcher: ……………………………………..

Date: ………………..

Signature: ……………………………………………….

(ix) Consent form –Online teachers

Title of project: Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for grade 12.

Name of researcher: Angeline Duma

I, …………………………………………………..agree to participate in this research project.

I agree to the following: (Please circle the relevant options below)

1. The research study was explained to me.	YES	NO
2. I understand what the study is about.	YES	NO
3. I agree / volunteer to take part in this study.	YES	NO
4. I agree that I will be interviewed, and audio recorded.	YES	NO
5. I agree that the pre-recorded video I produce will be observed and analysed.	YES	NO
6. I agree that direct quotations from the observation transcripts may be used by the researcher in their research report.	YES	NO
7. I understand that my participation will remain anonymous (my name will not be used by the researcher in their research report).	YES	NO
8. I understand that I will not be paid for my participation in this study.	YES	NO
9. I understand that I can stop being part of the study at any time.	YES	NO
10. I understand the risks involved in the study.	YES	NO

Please **print your name and sign** below
Name and surname: ………………………………………
Date: ……………………………………………………
Signature: ………………………………………………

Name of researcher: ……………………………………..
Date: …………………...
Signature: ……………………………………………….

Appendix D: Interview Protocol

Teacher Interview questions

1. What was the main aim of the lesson? What goals were you trying to achieve in this lesson?
2. Is the concept of using different forms of knowledge or knowledge structures a familiar concept to you?
3. Looking at your lesson, do you think you managed to use different knowledge forms or a variety of practices?
4. What forms of knowledge do you think you managed to integrate in this lesson?
5. What are the factors and dynamics that influenced how you taught this lesson?
6. If you were to reteach the same lesson, what would you change or taking into account forms of knowledge?
7. Tell me about the challenges you had when recording the video for your lesson? (online teachers only)
8. How long have you been teaching Technical Sciences?

Appendix E: Technical Sciences CAPS Document

https://www.education.gov.za/Portals/0/CD/National%20Curriculum%20Statements%20and%20Vocational/CAPS%20Science%20Tech%20bleed%20and%20crops.pdf?ver=2015-05-18-144638-000

Appendix F: Observation Protocol

Observation Protocol for organic chemistry Lessons
Title: Integrative knowledge building in distance and contact sessions: An exploratory study of organic chemistry lessons in Technical Sciences for Grade 12
Researcher: Angeline Duma

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1. **Purpose of the observation**

To capture how Technical Sciences teachers build integrative knowledge during the teaching of organic chemistry, focusing on:
• The structuring of knowledge (Positional Autonomy – PA)
• The purposes and connections of knowledge (Relational Autonomy – RA)
• The practices and strategies that foster or constrain integrative knowledge building in contact and online lessons.

2. Observation Focus Areas
The observation is guided by the research questions and autonomy codes from LCT.

Focus Area	Observable Indicators	Example Questions for Field Notes
Lesson Structure & Flow	Clear lesson introduction, transitions between concepts, closure	How is the lesson structured from introduction to conclusion?
Knowledge Practices (PA)	Source of knowledge: within or outside curriculum	Does the teacher draw from curriculum knowledge or other domains?
Purpose of Knowledge (RA)	Purpose for introducing specific knowledge	What purpose does the teacher attach to each concept?
Integration of Knowledge Forms	Links across disciplines, contexts, or everyday life	Are there explicit links to real-world or cross-disciplinary applications?
Pedagogical Strategies	Methods used (explanation, questioning, demonstration)	What strategies promote engagement or understanding?
Learner Engagement	Verbal/non-verbal responses, participation	How do learners respond to questions or examples?
Use of Technology (Online Lessons)	Use of multimedia, clarity, pacing, interactivity	How effectively does technology support integrative understanding?
Language & Communication	Use of analogies, examples, or metaphors	Does language simplify or complicate integration?

Evidence of Knowledge Shifts (Autonomy Pathways)	Shifts between sovereign, projected, exotic, or introjected codes	What movement is visible across knowledge codes during the lesson?

3.Observation Recording Format

Segment	**Time Stamp**	**Activity Description**	**Knowledge Code (PA/RA)**	**Observed Integration**	**Researcher Notes**