The power of discourse in high school adapted science with English language learning students

by

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Ethics Statement

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Abstract

The significance of teacher and student interactions in classrooms as a means of enacting curricula, analyzing learning gains and embedding classrooms into broader societal power relations needs to be emphasized. In the context of science classes with English language learners (ELLs) in Canadian high schools, language learning and content learning goals are intertwined. In this study, I focused on the question of how I can help ELLs master science literacy, communicative literacies, and knowledge-based critical reasoning skills without simplifying the curriculum. I designed and delivered lessons for an adapted (transitional) science class of fourteen grade 10 ELLs over two semesters. I video-recorded all class activities and analyzed the data using the Communicative Approach framework, the Genre Egg framework, the Cognitive Discourse Functions construct, the 5R Instructional Model, and the Teacher Language Awareness construct. My data showed that adopting pedagogical practices via dialogic discursive interactions that create room for different points of view benefited ELLs in acquiring academic literacy. Furthermore, language accommodation did not seem to hinder or shift dialogic discourses into presentation and lecture-style authoritative teaching. However, the data also revealed the challenges of advancing content and language objectives in the same lesson under time constraints and given the reality of teacher training for adapted teachers in science. I argue that raising the content awareness of language teachers and the language awareness of content teachers has the potential to promote a genre-based, dialogic pedagogical approach in legitimizing learners' views while offering access to dominant science perspectives in order to help ELLs develop criticality and maintain science identities as valued members of a high school science community. I reflect on the challenges in doing this and some of the strategies to overcome them. I conclude that the future of adapted teaching needs to endorse rigour as opposed to simplifying content, promote dialogicity instead of unilateral information-giving, utilize learners' diverse pools of knowledge and experiences rather than leave them out of the curriculum, teach text-in-context as opposed to isolated language lessons, and foster critical thinking via reasoning and argumentation of today's global issues to truly benefit language learners in developing science literacy.

Keywords: English language learners; content-based instruction; classroom interaction; classroom discourse; teacher language awareness; pedagogical content knowledge

Dedication

I dedicate my research to my mother who has been my source of inspiration in being an educator. She had a long career as a high school teacher in Iran, caring for her students deeply. She always saw them first with the lens of a mother and then as a teacher. She learned their individual differences, the hardships they were facing and the dreams they were reaching for. She took all of that into account when designing her lessons. I recall the high-stakes exam papers she would bring home and how every effort would go into affording a student a few scores here and there so that they could earn a passing grade. Her students still remember to call her on international "teacher's day". Her love for her students painted an image for a me of teaching as a career driven by passion and humanity. Thank you, Mom!

I would also like to dedicate this humble research to my husband who has supported me to persevere and to see the light at the end of the tunnel. I am grateful for his sense of comradery and cooperation in caring for our three children who needed to be looked after and entertained while Mommy was busy reading and writing. I could not have done this without a kind and loving partner!

To my three gems - my pride, my heart & my joy - I dedicate my dissertation to you for all the hundreds of hours that you played with LEGO, read books, watched something "educational", and created drawings, comics, paintings, and paper airplanes all by yourselves so that Mommy could study. You showed me great consideration, love, and deep care beyond your small years. You saw me work hard and you learned that investing energy and time into achieving a goal close to your heart is worth the hard work.

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> There is a field somewhere,
> Beyond all doubt and wrongdoing.
> I'll meet you there. (Rumi, 1207-1273)

Dr. Angel Lin kindly agreed to join my committee as my data needed her skillful vision to find the potential in the many hours of collected data. Her timely advice, meticulous scrutiny, resourceful references, scholarly feedback and effective scaffolding have helped me to a very great extent to accomplish this task. I am honoured to have learned from her and implemented her expert advice in my dissertation.

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List of Acronyms

ADI	Argument-driven Inquiry
BICS	Basic Interpersonal Communication Skills
CA	Communicative Approach
CALP	Cognitive Academic Language Proficiency
CBI	Content-based Instruction
CCBI	Critical Content-based Instruction
CDF	Cognitive Discourse Function
CLIL	Content and Language Integrated Learning
DCK	Disciplinary Content Knowledge
ELA	English Language Arts
ELL	English Language Leaner
ESL	English as a Second Language
GMO	Genetically Modified Organisms
GRT	Genre and Register Theory
KMT	Kinetic Molecular Theory
LAC	Language Across the Curriculum
PCK	Pedagogical Content Knowledge
PLK	Pedagogical Language Knowledge
SEL	Social-emotional Learning
SFL	Systemic Functional Linguistics
SFU	Simon Fraser University
SLA	Second Language Acquisition
SMK	Subject Matter Knowledge
TESOL	Teaching English to Speakers of other Languages

TLA	Teacher Language Awareness
WVSD	West Vancouver School District
ZPD	Zone of Proximal Development

Chapter 1. Introduction

1.1 The Context of Content-Based Teaching and Researching

Educational research is a design science in which different curricular, pedagogical and classroom designs motivate and enhance understanding about different educational practices (Cope & Kalantzis, 2000). Educational practice is a topic of great importance, not only in the sense of classroom activities but also in terms of "how classroom interaction is influenced by the societal discourses that surround educational practices" (Cummins & Davison, 2007, p.963). These two aspects of educational practice need to be reflected in school-based language policies with regards to how to ensure classroom activities offer relevant, rigorous, and authentic grade-level curricula to students from diverse language background, and how to utilize learners' linguistic and literacy backgrounds as a resource and an instructional asset in order to keep up with the demands of 21st century knowledge society (Cummins & Early, 2015). How do students from non-dominant languages advance in science and technology in Canadian high schools? What are the social and global outcomes of language and content learning? And why is it crucial for the teaching of language in the context of science education to echo today's global issues and the planet's crises?

To answer these questions, one needs to rethink the fundamental premise of pedagogy and to teach criticality: to equip students with cultural, linguistic and economic capital that helps them participate in the construction of their identities and their social futures (Cope & Kalantzis, 2000). Teaching criticality in relation with one's pedagogy, will need to highlight the tenets of what Cope and Kalantzis (2016) identify as "reflexive pedagogy" to embrace both teaching the orthodoxy of the conventional ways or "knowledge that is imposed" and using authentic pedagogy which reflects demands of society and "trueness-to-life" (Cope & Kalantzis, 2016, p. 46). This nuanced and intertwined approach to pedagogy is what I hope to achieve in this research via teaching language learners in the content of science and via analyzing teacher-student interactions to show where pedagogy needed to address the conventional perspectives and where it could extend itself to greater societal power relations and the imminent questions of the planet's fragile state.

In this chapter, I will first discuss the current demographics of students from diverse language backgrounds in Canadian schools and then I will discuss the terminology I find appropriate in labeling this group of learners and the instructional approach I have selected. I will continue by highlighting my impetus for doing this research, my personal and professional background, as well as the objectives of the research and the breakdown of the chapters in this dissertation.

1.1.1 Demographics

Demographically, one out of five people in Canada's population of over 33 million is foreign-born and one out of every three children in Canada is from a family where both parents were born in another country (Statistics Canada, 2016). In a seminal book, *Immigrant Student Achievement and Education Policy* (Volante, Dlinger, & Bilgili, 2018), it is projected that by 2036, one out of every two children in Canadian schools will be a child of immigrant parents. The children of immigrants who arrived in Canada over the past several decades are quite diverse in terms of ethnicity and source country. This heterogeneity reflects differences in vulnerability and resources between immigrant groups, where language abilities, employability, socio-economic status and later-on post-secondary enrollment vary widely (Cheng & Yan, 2018; Ilieva, 2016). The achievement gap between members of the two immigrant classes, the skilled workers class and the families and refugee class, is noticeable and concerning (Organisation for Economic Co-operation and Development or OECD, 2016). Immigrant students in British Columbia and Ontario who are largely of the highly educated and skilled workers class score higher in academics compared to their non-immigrant peers; whereas, in Alberta and Quebec, non-immigrant students slightly outperform their immigrant peers coming from the families and refugee class. Thus, in Canada, the educational outcomes of children with a migration background are complex and such results need to be interpreted with caution (Cheng & Yan, 2018). A few studies have reported that differences in English proficiency level upon entry to high school as well as the differences in vulnerability and resources between immigrant groups are correlated with academic achievement (Garnett, 2012; Gunderson, 2007; Hou & Bonikowska. 2016). To close the achievement gap, empirical research has shown the importance of inclusion: including immigrant students in mainstream classrooms along with their non-immigrant peers (see British Columbia Ministry of Education, 2017; Gunderson, 2007; Gunderson, D'Silva, & Odo, 2012; Toohey & Derwing, 2008). It has been pointed out that "[how] well immigrant students do at school is not only related to their attitudes, socio-economic status and prior education, but also to the quality and receptiveness of the host country's education system" (OECD, 2016, p. 274). Perhaps adapted learning environments can offer a solution for the eventual and true inclusion of this special group of learners in the mainstream classrooms to close the achievement gap and the English divide.

1.1.2 Terminology

In this section, I will briefly justify the selection of the terms ELL and CBI, which I will use in this dissertation, from a myriad of other similar terms. Among other commonly used acronyms in second language acquisition (SLA) settings, such as English as a second language (ESL), English for speakers of other languages (ESOL), English as an additional language (EAL), Limited English proficient (LEP), or L2 Speaker, the term ELL (which in the BC Ministry of Education documents stands for English Language Learning) could be equally problematic as it privileges English and ignores the many other languages in which the learners have proficiency (Ilieva, 2016). The root of this problem stems from views of learners of English from a deficit perspective. English language programs with a deficit approach, where the home cultures and home languages of minority students are viewed as inferior (Cazden, 2011; García & Wei, 2014; Hull & Schultz, 2002) do not foster the critical engagement necessary in bridging the language divide, utilizing learners' wealth of prior knowledge, and viewing them as emerging bilinguals (García, 2002).

The term "ESL" has been commonly used to refer to students in government funded programs that traditionally specialized in instructing students to acquire English for schooling or integration purposes. To account for the many learners already proficient in more than one language, the term English as an additional language (EAL) learner has been used in Canada in the last several decades. Although the above acronyms and connotations place great emphasis on English as the end goal and overlook multilingualism, multiculturalism or multicompetence (Cook, 1999), I have chosen to use the term ELL as it is the term used in the BC K-12 system (e.g. BC Ministry of Education, 2018) and because, according to Garcia, Kleifgen and Falchi

(2008), it could open up a view of learners as “emergent bilinguals” or multilinguals in an English medium, and I acknowledge throughout my dissertation that ELL students bring a rich heritage of culture, scientific knowledge and multilingual proficiencies into the science classroom.

Regarding the second term I will be using throughout, CBI, the facilitation of language and content in the same lesson, with varying degrees of attention to the integration of the two, has been given many names, most commonly, content-based language teaching (CBLT), content-based instruction (CBI), language across the curriculum (LAC), content and language integrated learning (CLIL), sheltered instruction, and immersion. In the context of the present study in a Canadian secondary school with the objective of preparing ELLs to participate in mainstream science, I have chosen to refer to this kind of adapted teaching as CBI, where subject matter becomes accessible to learners via a language they are acquiring simultaneously while learning content. CBI theorizes language structures to be most effectively acquired when situated in appropriate communicative context (Halliday & Matthiessen, 2004; Johnson, 2009; Krashen, 1985; Lave & Wenger, 1991; Stoller, 2008). Under the umbrella of CBI, my teaching resonated closely with an adapted approach where content took centre stage and language support catered to making content accessible. This type of instruction, according to Stoller (2008), relies on modification of text, assignments and tests by paying explicit attention to language features, in order to make the content comprehensible to the learners; however, assessment is solely based on demonstrating gains in content knowledge. This approach was reflected in my curriculum design, learning objectives and assessment goals in this research.

1.1.3 Impetus

The impetus for my research stems from my work with ELLs in high school science grades 10, 11 and 12 over a duration of five years. I saw a real demand for curricula that address the needs of these senior level students in both language acquisition and access to career learning opportunities on par with their English-speaking peers in an ever-evolving society where language diversity and multimodal literacy are realities that cannot be left out of school curricula. I see schools as social and educational institutions responsible to provide access to opportunities by offering curricula that is rigorous, relevant and authentic, and by providing training programs to teachers so that they are capable of facilitating successful lessons. So, how do teachers enact their epistemological beliefs when planning a CBI curriculum and how do they facilitate shifts in discourse that encompass the principles of dialogic and authoritative approaches to the benefit of their students in high school adapted science?

Negotiating pedagogy is often dependent on teachers' epistemological views and the socio-political climate dominant in our schools (Cummins & Early, 2015; Cope & Kalantzis, 2016). The discussion of orientation to pedagogy becomes central to me in that teaching takes place in a matrix of power relations where pedagogy can be both empowering and constraining depending on teachers' epistemological views. Pedagogy plays itself out in teacher talk, curricular content, student-teacher interactions, students' lives and the hidden "Discourse" of the classroom (Cummins & Early, 2015; Early & Kendrick, 2017; Gee, 1999; Lin, 2016; Mortimer & Scott, 2003; Norton & Toohey, 2004). My orientation to pedagogy stems from my constructivist and participatory ontological views, which will be explained in the methodology chapter of my dissertation. From these perspectives, student-teacher interactions serve a dual purpose to "transmit not only conceptual knowledge and language/literacy competencies but also messages about identity, belonging, opportunities, and entitlement" (Cummins & Davison, 2007, p. 971). My pedagogical orientation is also influenced by my personal and professional background. In the next section, I will describe my personal journey in arriving at the intersection of identity, agency, knowledge, experiences and societal roles which collectively shaped the way I approached my research topic and gave me the lens with which I viewed pedagogy as identity and curriculum design as a tool to advocate for the voiceless and the marginalized.

1.2 Personal and Professional Background

My life in Canada began at the age of 16 when my family left behind scant opportunities available for my parents to raise two daughters in Iran, and moved to Vancouver in search of a better life. With no proficiency in English, I was enrolled in grade 10 with a time-table dedicated to regular grade 10 courses, such as science, math and social studies as well as two blocks of ESL and one block of ESL support. I recall sitting in grade 10 science feeling deaf, dumb and mute. Decoding a new language to learn content felt painfully slow and permanent. I saw no light at the end of the tunnel and I felt I owed my science teacher so much for his patience and for the happy faces he would draw on my blank 5-minute quizzes each day. I asked myself, if I were a teacher, would I tolerate a student in my class who could not answer a single quiz question? As a sixteen-year-old, I could not see far enough; there was indeed light at the end of the tunnel. Before I knew it, I was answering most of the 5-minute quiz questions and Mr. Garby did not have to draw a happy face for a zero any longer.

As an undergraduate student, I studied science for four years at the University of British Columbia. I chose Biochemistry as my major and most of my courses were initially concentrated in Chemistry and Biology and gradually focused on Biochemistry. After earning my bachelor's degree in Science, I then pursued a degree in Education to become a high school science teacher. I was accepted into the cohort of Chemistry, where I was trained primarily to teach Chemistry, but also some Biology and Physics. Mr. Garby was there in charge of the Chemistry cohort. Like him, the other instructors were veteran teachers who had taught their specialized courses to high school students for most of their careers. There in the university classrooms, these teachers transferred their knowledge and expertise to preservice teachers; how to design lesson plans and how to make them engaging. They also taught some theory courses to guide the student-teachers in defining their philosophy of education: what is the role of the teacher in the classroom and how do you see your role in relation to your students?

The practicum portion of the teacher training took place in a high school near my house with a sponsor teacher who taught senior level Chemistry and junior level Science. I started observing and gradually teaching portions of his classes and ultimately took charge of 80% of his teaching load. He offered to me feedback on the lessons and on my classroom management style. Finally, a faculty member who was a retired school principal came to observe me several times during my 4-month teaching practicum and he wrote rave reviews on my reference letter. He wrote that "Nikta is an excellent teacher because she does not like standing in the front of the classroom and lecturing."

Thus, I graduated feeling confident in having acquired the necessary skills to teach students "about science". However, nothing in the coursework, workshops or practicums throughout my Education program prepared me to adapt or design my teaching methods to meet the needs of English Language Learners (ELLs). To have gained pedagogical knowledge for content delivery seemed sufficient to make me a qualified teacher to guide, support, encourage, empower, stimulate, modify and teach students from all walks of life. As Cummins and Early (2015) point out, the dominant assumption for faculties of education in teacher training in Canada is that teaching ELLs is the job of the ESL teacher and only recently optional courses in education programs have been offered to preservice teachers who wish to gain expertise in teaching ELLs. In most cases, teachers discover the challenges of adapting and molding their pedagogies on the site in the absence of effective support or leadership in linguistically diverse schools, as was my experience.

After teaching science for two years with the Vancouver School Board, I slowly recognized that while I lacked skills in teaching my students from non-dominant language backgrounds; due to my own early struggles, I had awareness of their needs-their emotional needs, social needs, and academic needs. I felt that I could identify with them, their struggles and their dreams. There I recognized that I was able to draw from my own journey and experiences of learning English in adolescence in mainstream content classes to encourage my students and to help them see the light at the end of the tunnel. But I did not have sufficient skills to teach them language and content in tandem. The fact that I knew the language and the subject matter, did not assist me in teaching the specialized language of the discipline. But what was exciting was that at times I could sense where the gaps were; I knew which verbs might be problematic and which expressions foreign. I knew that maybe paragraph writing does not follow the format of an introductory sentence and supporting details, and I knew how difficult it is to judge when concise, “business style” writing is more appropriate than writing that appeals to reader’s emotions. I also knew that my experienced and caring colleagues in other science classes teaching the same students perhaps did not see the emotional and social needs, the gaps and the misconceptions the way I saw them.

So, my desire to train as a teacher of “English as a second language” was motivated by the changes that I wanted to bring to a system in which my ELL students were placed. I applied for a master’s degree in TESOL and despite lacking all the pre-requirements in Linguistics, I was accepted. Later, the program administrators told me that my background as a science teacher and the fact that I learned English in high school influenced their decision positively. They felt that I would be able to comprehend the theories in SLA, bilingualism, Education research methodology, and bicultural studies due to my personal and professional background. I learned a wealth of knowledge in the master's program and brought what I learned into teaching ELLs in a variety of settings: SFU's ELC program working with exchange students from Korea who hoped to be immersed in the environment and improve their conversational skills, and UBC's ELI program teaching enthusiastic science teachers from Mexico who taught their core curricula in English and as part of their professional development enrolled at ELI to advance their academic English proficiency.

But the real learning took place when I was hired in a high school, located in an affluent area where the ESL department was offering "transition" science courses to the ELL population. The "transition" courses resembled "sheltered" or theme-based courses where students developing the dominant language of the school were pulled out from mainstream classes and placed in adapted classes. Students were placed in transition if they did not pass their language assessment and regardless of their language ability levels, they were grouped according to age. Transition science 1 consisted of ELL students in grades 8 and 9 where they learned body parts, mixtures and solutions, and some basic topics in physics, such as gravity. Transition science 2 consisted of ELL students in grades 10, 11, and 12 studying basically the same topics but with fewer visual cues and more text. These topics had been decided on and used by the two language teachers who acted as the ELL department heads. The lessons had been photocopied and repeated every year. Once I was put in charge of teaching Transition Science 1 and 2, I realized that the needs of the students were not met because the material did not match what students in mainstream science were learning in the corresponding grades. Through no fault of the caring ELL teachers, their lack of content knowledge resulted in a watered down and elementary approach. What is more, the students did not have access to any lab equipment. After two years of teaching in the transition program, I had altered most of the teaching material and brought microscopes, beakers and heat plates into my classrooms. In this process, I became inspired to investigate my journey into researching the possibility of designing and delivering a curriculum relevant and on par with the learners' grade level. Here, my knowledge base became a key factor not only in the ability to design the appropriate curricula but also in the ability to evaluate my teacher knowledge base in content, in pedagogy and in language, not only the language of the instruction but also the language of the discipline, and not only in understanding the discipline-specific language, but also in teaching it.

1.3 A Critical Lens

The goal of creating access to the language of schooling, work, power, and community through meaningful opportunities will not emerge if the approach to adapted/sheltered content courses in high school is simplified and watered-down. According to Cope and Kalantzis (2016), learning is “incidental, casual and informal” whereas, pedagogy is “conscious, premeditated and structured” (p. 70). Therefore, it is crucial that learning becomes interactional - a product of pedagogy emerging and in relation with societal powers. Using language as a lens to look at pedagogy is critical in that language constructs and reflects specific socioculturally defined contexts (Gee, 2002, 2004) - contexts that are responsible for fostering students’ growth.

My teaching experience, which is also echoed in Bunch (2013), Fry (2007; 2008), Janzen (2008), Oliviera and Weinburgh (2017), Slater and Mohan (2010), Wu, Silveus, Vasquez, Biffi, Silva, and Weinburgh (2018) and many other research studies, showed that there was a lack of relevant content in adapted science courses. Cutting down and simplifying grade-level content in transitional or adapted programs perpetuate marginalization of language-minority students and reinforce the persistence of the academic achievement gap between these students and students from language-dominant backgrounds because access to disciplinary genres, styles and registers allows ELLs to successfully participate in school literacy tasks and achieve distributive justice (Fraser, 1995 in Lin, 2020). Awareness of the requirements of the content-area register and engagement of students in relevant content-area tasks have been shown to help ELLs discover how language works in academic discourse and to enable them to feel empowered (Janzen, 2008; Lin, 2016; Slater & Mohan, 2010).

Senior level students in transitional science have been taught science topics suitable for a younger audience as this has been the only tool available to language teachers when teaching content that requires SCK (Specialized Content Knowledge) as Ball, Thames and Phelps (2008) point out. Potential lack of rigorous curricular content in adapted science that makes fewer cognitive demands and leaves out more academic genres and registers required in college, translates into transitional or “dummied-down” classrooms marginalizing ELL students (Bunch, 2013; Leki, Cumming, Silva, 2008; Lin, 2016). Alternatively, when adapted courses are taught by content teachers - experts in the discipline of the subject matter who lack awareness of the language of the discipline

(Andrews, 2007) - the learners are not given the tools via language of the discipline to access the knowledge for disciplinary meaning making (Bunch, 2013). These persistent inequities in CBI inhibit ELLs from participating in the same kinds of intellectual work that inquiry-based and argument-driven science can offer to build knowledge and skills (Durán, 2008; Fry, 2007; 2008).

1.4 Research Objectives

I saw great urgency in research exploring this topic via discourse analysis with the possibility of designing material that encompasses the linguistic needs of high school science without simplifying the content for teachers who are either trained in teaching content or trained in teaching language but not trained in both as this seems to be the reality of adapted classrooms in today's high schools in Canada. The idea of pursuing post graduate studies in this area appealed to me and I searched for programs compatible with my research interest. The Languages, Cultures, and Literacies Program at Simon Fraser University encourages students to broaden their horizon by critically examining the cultural and linguistic diversity that characterizes contemporary classrooms globally. I found my research interest to be a good fit within this program where supervisors are spearheading cutting edge research in the area of applied linguistics and teacher training. The wealth of knowledge I gained from the Languages, Cultures and Literacies Program was instrumental to my research design and the writing of my dissertation. I have organized my dissertation in a way that I hope my readers can follow my logic and train of thought clearly. The dissertation will take the readers through the followings chapters:

Chapter 1. **Introduction:** highlighting the importance of my research questions and narrating my personal and professional background

Chapter 2. **Literature Review:** delineating knowledge that exists in related literature and the perspectives and frameworks grounding my research

Chapter 3. **Study Design:** depicting my ontological and epistemological views as well as ethical considerations and methods of data collection and analysis

Chapter 4. **Data Analysis and Findings:** examining classroom discourse and students' academic gains in order to find the emerging thematic patterns

Chapter 5. **Discussion and Implications:** making sense of the findings in a larger scope and making recommendations for future teacher education and research in this field

The chapters in my dissertation address a unifying goal: to shed light on classroom discourse to enhance students' conceptual and linguistic gains, as well as to enhance students' sense of legitimacy and confidence in content classrooms. Furthermore, preservice teacher training programs can benefit from the implications of this research in terms of identifying the types of knowledge required of teachers in adapted settings. Similarly, in-service teachers can gain insights exploring the pedagogical inquiries a teacher has had to navigate through to become a confident teacher in high school adapted science classrooms.

Besides, a teacher's development of content and language awareness in meaningful ways can facilitate the learning outcomes of the students (Lin, 2016) where they display science literacy as well as knowledge-based critical reasoning skills to question the status quo. This is exactly why the social discourse of a science classroom through pedagogy needs to extend itself to teaching the genre of debate, knowledge-based arguments and reasoning as well as reading between the lines in order to create the capacity for building conditions which manifest into full and equitable social participation for ELLs. Particularly, the matter of *knowledge-based* reasoning is key. The advancement in knowledge comes hand in hand with students' abilities to read between the lines, to question and to make connections. Plain reasoning and argument-driven inquiry in the absence of teaching the dominant discourses will not promote students' growth and cognition. As Scott, Mortimer, & Aguiar (2006, p.607) claim, student's accountability to "disciplinary norms" builds reasoning skills and capability in considering multiple viewpoints critically and assists them in coupling their claims with scientific evidence.

In summary, my study aims to examine the discursive interactions in an adapted science classroom pedagogy with the potential to advance knowledge for adapted science teachers, as well as to assist ELLs in high school where graduation and later-on access to workplace opportunities are challenging (Bunch, 2013; Cummins, Mirza & Stille, 2012; Gunderson, 2007; Janzen, 2008; National Research Council, 2017; Toohey

& Derwing, 2008). The importance of teaching students the genres and registers of academic disciplines without privileging a linear hierarchical path which implies students' familiar home and cultural languages and practices as inferior, has been at the forefront of critical research (Cummins, 2017; Dalton-Puffer, 2013; Flores, 2013; Janks, 2004; Lemke, 1990). The impetus for my study is to bring insight into the expansive knowledge that is necessary for teachers to provide access to the established genres and registers in adapted settings by fostering language development, reasoning skills and understanding of science concepts while also raising critical awareness to "destabilize the privileged position of academic literacy" (Lin, 2020, p.4) and to view minoritized students' literacy practices as valuable and legitimate.

How might an inquiry-driven pedagogy unfold in a CBI science class and what can we learn from this process in relation to 1) classroom discourse, 2) English language learners' educational outcomes in terms of academic literacy, and 3) teacher language awareness? My goal is to accomplish this task by asking the following broad questions while exploring my teaching in the context of an adapted science classroom in senior level high school in Canada: 1) how to view the social language of the science classroom not only as a tool to learn content but as a meaning-making resource allowing access to learning opportunities? 2) how to make subject-matter content comprehensible to learners, whose knowledge of the language of instruction is only partial, without simplifying the curricular content to the extent of shortchanging students? (Hoare, Kong, & Bell, 2008), and 3) what kinds of knowledge do teachers need in order to design and deliver CBI curricula? I will continue to focus on these broader questions and offer a literature review on the diverse research traditions in educational context examining these topics in the next chapter. At the end of chapter two, I will reframe these broader questions in more nuanced ways to form my own research questions which can be answered within the scope of my dissertation.

Chapter 2. Literature Review

2.1 Introduction

The interest to combine content learning with language learning dates back to the late 1980s when a surge of research studies highlighted the positive outcomes of teaching language and content simultaneously (Brinton, Snow, & Wesche, 1989; Chamot & O'Malley, 1987; Mohan, 1986; Parker, 1985). The most significant inspiration behind CBI was rooted in the French immersion programs in Canada (Brinton et al., 1989; Dueñas, 2003). Other inspirations also reflected the demands of societies: increased global communication (Stoller, 2008) and research on cognitive processing of learning and language awareness (Lin, 2016; Marsh, 2008). With diverse pedagogical and curricular implications, CBI is a tool with the potential to address the needs of minority students learning non-linguistic curricular content in schools via a language medium foreign to them, often lacking equal access to the linguistic and curricular knowledge capital that speakers of majority languages have (Bunch, 2013; Durán, 2008; Fry, 2007, 2008; Janzen, 2008; Stoller, 2008). What holds promise to diminishing this inequality is positioning the learners as members of the scientific community even when language is modified and setting is adapted (Callahan, Sampson, & Rivale, 2019). This necessitates that CBI teachers are equipped with a toolkit drawing on critical pedagogy that is inquiry-based and argument-driven, along with viewing bilingualism as a resource and not a problem to overcome. While critical pedagogies in CBI alone cannot contest systemic raciolinguistic discrimination (Alim, Rickford, & Ball, 2016; Museus, Palmer, Davis, & Maramba, 2011), they can begin, as a tool, to shift the discourse of the classroom to invite genuine dialogic interaction (Mortimer & Scott, 2003; Scott, Mortimer, & Aguiar, 2005) and teach ELLs the language to engage in science processes and to eventually develop science identities along with academic literacy.

In my literature review, I will examine previous research on the role of classroom discourse in high school science as well as in CBI settings enacting an inquiry-based and argument-driven science curriculum. I will offer a picture of the findings from similar studies in a CBI setting, whether they are presented as CLIL studies, immersion, discourse analysis, language instructional models or teacher knowledge studies. Collectively the studies have a unifying thread of focusing on the nuances of pedagogy in achieving a common goal: bettering learning conditions in the intersection of content and language teaching. This chapter is organized in six main sections: CBI, The Communicative Approach Framework, Teacher Knowledge, Identity and Empowerment, the existing gaps in literature, and my research questions.

2.2 CBI

2.2.1 Theoretical Grounding for CBI

With no particular theory directly responsible for the construct of CBI as a pedagogical model addressing SLA, a myriad of theoretical frameworks and perspectives have been instrumental in grounding this model over the past three decades (see Lin, 2016; 2020). These theoretical considerations have important implications for curriculum design in adapted science. Sociocultural theories based on Vygotsky's work provide much of the grounding for CBI where learning not in isolation but in a social context has much to do with our modes of communication, culture-specific tools and hierarchies of power in society.

The zone of proximal development (ZPD) is an important aspect of sociocultural theorizing of language learning as it highlights the stages of appropriation or in other words, *internalization* which I will discuss further in section 3 of this chapter. In cognitive learning theory, Vygotsky's ZPD (1978) and the notion of "scaffolding" offer the basis for CBI. The ZPD in language acquisition refers to the individual's potential development when working with others as opposed to when they work independently. This can be done through teacher's "scaffolding" by offering the learner extensive instructional support in order to fill in gaps in knowledge (Chamot & O'Malley, 1994). In the area of teacher scaffolding, Walsh (2011) drew from Kramsch's interactional competence (1986) to study how language learners utilize semiotic tools such as turn-taking, repair, overlap and interruptions, as well as topic management to maintain the progression of dialogue. The pedagogical implications from Walsh's study make conspicuous for teachers the nuanced features of scaffolding, wait time, paraphrasing, elicitation and reiterating which altogether enhance and shape leaners' contributions. In my data analysis, I make references to these pedagogical tools under the umbrella of teacher feedback and discuss where and how my feedback opened or closed channels of communication and how meanings were co-constructed in the unfolding interaction as Walsh outlined in his study.

Other frameworks influenced by constructivist learning theory, such as Krashen's (1985) model of "comprehensible input", provide a theoretical foundation for CBI which became the groundwork for a popular instruction approach known as "sheltered instruction observation protocol" (SIOP) (Echevarria, Vogt, & Short, 2004). SIOP in CBI uses meaningful instruction to provide scaffolding and frontloading of vocabulary that contextualize content instruction in a way that lowers the linguistic demand but allows for content to develop in conjunction with language. However, SIOP has been problematized for its linear sequence of instructions, frontloading of vocabulary and articulating lesson objectives prior to the lesson as being at odds with science disciplinary practices which are often explorative and inquiry-driven (Krashen, 2013; Oliveira & Weinburgh, 2019; Weinburgh, Silva, Horak Smith, Groulx, & Nettles, 2014).

Another construct in SLA also offers insight into content area teaching. Cummins (1980, 1996) makes a distinction between two types of language proficiency: Basic Interpersonal Conversational Skills (BICS) and Cognitive Academic Language Proficiency (CALP). The former is used when in exchange with others in everyday conversations and the latter is used when reading, writing, presenting or debating in academic and professional settings. Many experts in the field have criticized the BICS/CALP distinction for its duality and/or for its opposition to each other: BICS as contextualized and CALP as decontextualized. Ranney (2012) argues that both types of proficiency should be viewed as having their own contexts since academic language is also largely contextualized. Blynd (2011) explains that the problem lies in the absence of an understanding of the underlying cognitive processes involved in second language development which is echoed in Aukerman's criticism (2007; 2013) that students' home knowledges are and can be defined as CALP because children that learn at home apply their learning as a form of CALP in interpreting phenomena and experiences in their surroundings. Flores (2013) and Flores & Rosa (2015) posit a criticism in the purview of critical raciolinguistics to problematize the arbitrary privilege appointed to standard English as the only correct way of using language especially in academic practices while devaluing the significance diverse home languages, literacies, and registers have on expanding, appropriating, and meaning making of academic language and disciplinary knowledge. Critical views of non-hierarchical language teaching promote a shift away from “linguistic homogeneity” and “monolingual pedagogical approaches” (Flores, 2013, p. 501) towards additive approaches where diverse linguistic and cultural practices of minoritized students are legitimized and valued while standardized and mainstream language skills are also taught. Such arguments have much application in my research as I strive to make sense of students’ prior knowledge in their home cultures - or as Mortimer and Scott (2003) call it, their “everyday knowledge” - shaping and constructing the process of meaning making in the discipline of science. The key to making additive approaches successful is what Aukerman (2011) delineates as creating socially meaningful participation for ELLs which reinforces my research objectives of engaging students in dialogic science learning and knowledge-based reasoning, which will be discussed in the later sections of this chapter. For now, the focus of my writing will shift to the teaching of science within CBI where the challenge is to build connections across differentiated speech forms, from everyday language to disciplinary discourse, while context conveys meaning often rooted in societal discourses.

2.2.2 Academic Language in Science Teaching with ELLs

The language of science or academic language in science due to its grammatically encoded content, high semantic complexity, and low semantic decontexutalization diverges from everyday or conversational language and makes heavier demands on the part of all students, especially ELLs (Bunch, 2013; Lumbrears & Rupley, 2019; Slater & Mohan, 2010). Lemke (2004) states that the language of science is a unique hybrid in which natural language comes together with mathematics symbols and representations to communicate meaning. Learning can occur using scientific conventions in multiple modes such as verbal, mathematical, and pictorial (Wu et al., 2018). However, the heavy dependency of contextual meaning on technical or field-specific vocabulary molds most CBI programs into putting vocabulary at the forefront and building scaffolding activities around it. Also, as CBI emerged within traditional language pedagogy, the attention of teachers in content courses was mainly focused on language items such as vocabulary and grammar, where vocabulary is broken into categories of field-specific, instrumental or linking lexicons (Oliveira & Weinburgh, 2017; Weinburgh, 2014). As a result, how to teach vocabulary became the topic of much research to zoom in on the effectiveness of lexico-grammatical instruction in its timing of insertion, the context, and the tasks which could mimic “language-in-use”. I review research on vocabulary instruction in the next section.

2.2.2.1 Teaching academic vocabulary in CBI

In the area of teaching ELL students in content classes, Weinburgh and Silva spearheaded series of research studies to optimize science and language learning (Weinburgh & Silva, 2011; Silva, Weinburgh, Malloy, Smith, Marshall, 2012; Weinburgh et al., 2014; Oliveira & Weinburgh, 2017; de Oliveira et al., 2019). The aim of their research was to investigate a model of integration by measuring change in science content knowledge and academic vocabulary for their students as they engaged in inquiry-driven science experiences employing what they call the 5R Model. Their research was inspired by the work of Snow (2008) where providing “meaning-rich contexts” and building on “connections drawn between the unknown word and other known related words” (p. 78) became the pivotal focus in teaching science to language learners. The empirical data was generated in an in-class experiment with 110 fifth grade “newcomers” in Texas during six weeks spanning over two years (Weinburgh et al., 2014). The volunteer teachers instructed the students around the two topics of *erosion* and *wind turbines* using inquiry-based teaching where learners were to design a house considering earth’s energy systems. Each subsequent day, the students answered a question, such as “how will different environmental factors affect my newly landscaped yard?” or “what is the best design for a wind turbine for me to use at my house?” Students’ answers were video-recorded during oral interviews and their new ideas were implemented into the design of their houses. The data showed a clear gradual increase in both conceptual understanding of content and sophisticated language to communicate meaning by the elementary school students in the study. The authors concluded that the increased academic language and conceptual understanding were due to the use of a 5R Model of instruction by the volunteer teachers during the course of the experiment. The 5R Model became the topic of much research in multiple studies and in 2019, in a chapter of an influential book, “*Teaching the Content Areas to English Language Learners in Secondary Schools”* (2019), Oliveira and Weinburgh state that in practice, the 5R Model entails:

> the science instructor provid[ing] ELLs with *just-in-time support* (Bransford, Brown, & Cocking, 2002) in the form of well-placed interjections and

> vocabulary prompts while remaining unconstrained by a particular instructional sequence. (In de Oliveira et al., 2019, p. 253)

The 5R Model combines five simple teaching strategies (or 5Rs) for the contextualization of vocabulary in the specialist discourse of the classroom. Instead of frontloading of vocabulary which is a common practice in language instruction settings, but problematic in inquiry-driven science, the authors, Silva et al. (2012) worked on "having the language emerge during an inquiry-based lesson with *reloading* [emphasis added] of language occurring the next day/lesson" (Weinburgh et al., 2014, p.523). To address other aspects of vocabulary development in the intersection between language and science teaching, the model uses the other 4Rs - *repeating, revealing, repositioning and replacing* - as methods of instruction. Silva et al. (2012) claim that four of the strategies -*replace, reveal, repeat,* and *reposition*- can be employed as opportunities emerge impromptu within the lesson, and are therefore, "context-anchored". The fifth strategy -*reload*- allows the teacher to plan in advance for reinforcement of language previously introduced to the students and is thus, "context-reflective." Below is a short definition of each of the strategies or instructional "moves" that the teacher can employ (de Oliveira et al., 2019, p. 251):

- *Replace* is a type of move wherein the teacher provides ELLs with the academic term that can be used in place of the everyday term first used by the student. The teacher honors the non-scientific language and builds upon it as a natural way to develop both language and content.
- *Reveal* is a move wherein the teacher provides ELLs with an academic term that does not exist in everyday language. Because science has many new and unique terms, teachers must introduce students to new vocabulary as it is needed to further meaning-making.
- *Repeat* is a move wherein the teacher provides ELLs with multiple opportunities to encounter and express meanings using multiple modes. The teacher builds into the lesson authentic reasons for the re-use of language as a tool for understanding.
- *Reload* is a move focused on revisiting and re-examining words from prior lessons. During reloading, teachers can help students move beyond a definition to seeing the relationship between the ideas presented in the words.
- *Reposition*, the most complex, is a move wherein teachers encourage ELLs to adopt the specific communication patterns of science such as use of passive voice (e.g., "*it was observed that*…") and nominalizations (e.g., "*the representation of a 2s orbital shows* …"). Teachers use their own speaking to model the way to communicate scientifically. They also help students edit their written work to mirror scientific discourse.

The 5R instructional model, designed specifically for teaching science to ELLs, provides teachers with a more reflective approach to language-science integration “without reducing science instruction to a linear and fixed sequence of steps or phases that are mechanically followed” (Oliveira & Weinburgh, 2017, p.3).

In teaching the vocabulary of the language of the discipline, the topic of students’ own pool of vocabulary and its role in construing knowledge in terms of scientific meaning becomes pertinent. Brown and Ryoo’s (2008), conducted an experiment in order to examine the teaching of science as a language in a “content-first” approach with elementary school students. The authors foregrounded that scientific concepts exist outside the words that describe them while the science words serve as a resource for higher levels of specific conceptual understanding and consequently offer a more efficient mode of communication to speakers of the science community. Hence, science words are symbolic and representational, and scientific language is a representational form using symbols, mathematical forms and language. The authors postulated that treating science terms as the single possible way to describe a scientific phenomenon would impact students’ abilities to conceptualize scientific ideas negatively. With this in mind, they taught the concept of *photosynthesis* to two groups of grade 5 students where one group was exposed to non-technical and everyday language: “*plants make their own food and the good air that humans breathe in by taking water, light, and the air that humans and animals breathe out”;* whereas, the other group was exposed to academic and technical language: *“plants make glucose and oxygen by taking water, photons and carbon dioxide”* (Brown & Ryoo, 2008, p.540). The results showed that teaching scientific concepts in everyday or vernacular language prior to introducing scientific language improved students’ learning of concepts. In other words, separating the conceptual and linguistic components of science has a positive impact on science learning.

The result of this kind of research has great significance for CBI to prove that although ELL’s initial and non-technical words do not always use the standard forms and representations, they are close in description to scientific perspectives. Building on the learners’ common-place, everyday and non-technical vocabulary while acknowledging the value they offer in meaning-making and connection-building is a great starting place for CBI teachers. Mortimer and Scott (2003) suggest exposing students to differentiated speech and supporting their use in developing scientific understanding by employing purposeful scaffolding in a variety of discourses in order to enhance students' engagement with text. An integrated pedagogy of both acknowledging students' use of everyday language to describe scientific ideas as well as engaging the learners with a variety of text delineating the genre of the discipline would need to be investigated. How can teachers help students expand their knowledge of concepts beyond vocabulary to engage in the appropriate discourse? A review of register and genre-based pedagogies is next.

2.2.2.2 Teaching register, genre and lexico-grammar in CBI

A substantial and growing body of research suggests that teaching language and science instruction are complementary (Arkoudis, 2003; Gomez Zwiep & Straits, 2013; 2017; Lee, Buxton, Lewis, & LeRoy, 2006; Mohan & Slater, 2005; Stoddart, Pinal, Latzke, & Canaday, 2002). The language of science particularly requires both the essential knowledge of science and the literacy skills to decode the language with the goal of communicating in science. However, based on Halliday's work in the early 1990's, Schleppregrell writes:

> [I]t is not possible to "do science" using ordinary language; that the language of science has evolved in the way it has because the kinds of meanings that are made in scientific discourse call for new ways of using the resources of the grammar. From this perspective, new ways of using language is learning new ways of thinking. Learning content means learning the language that construes that content… (Schleppregrell, 2004, p. 18).

In the distinction between ordinary language and academic language, the discussion of Systemic Functional Linguistics (SFL) becomes relevant. SFL is a genre-based semantic-functional approach that has been used to unpack the linguistic complexity of content texts for disciplinary literacy instruction and to build logical reasoning of text organization and grammar patterns (Fang & Schleppegrell, 2008; Schleppegrell, 2004). SFL allows for the development of concepts, metalanguage and pedagogy in designing socially, culturally and academically responsive CBI curriculum and instruction, which is why genre and register research have been leading the field of CBI pedagogy. Mapping the Language Demands (Derewianka, 1990, 2011); The Genre School of Pedagogy (Rose and Martin, 2012); Reading to Learn (R2L) (Rose 2010, 2015); Cognitive Discourse Functions (Dalton-Puffer, 2013; 2016), and The Genre Egg framework (Lin, 2016) have influenced the field and created a metalanguage for content teaching and language teaching to integrate. SFL views language as a structure to construe the speakers' experiences of the world (Halliday, 2006; Dalton-Puffer, 2013); and thereby, in science, SFL lends itself as a framework to make cognitive science concepts accessible by showing how rational/structured and purposeful thought enacts language in the discourse of science. This discourse not only includes specialized vocabulary, but also includes particular ways of using language to describe observations, create hypotheses, and construct explanations. For instance, teaching the genre of laboratory report in science was examined using SFL as a theoretical framework by Slater and Mohan (2010). The authors found that in a collaborative environment, the language teacher and the science teacher needed to focus on taxonomy, information-structuring, cause-effect reasoning and problem-solving to be able to teach the requirements of the content-area register and tasks. Thus, register development based on SFL was hypothesized to be the key element in creating success in this study.

As meaning and form are dialectically related to one another, grammar becomes a functional meaning-making tool which reflects modes of communication in specific social context. This means that students need to learn to first, analyze the primary social goal of the text (genre) and then understand the three dimensions of the context - field, tenor and mode (register)- in order to be fully engaged in academic language learning (Halliday, 1994; Martin & Rose, 2007). To understand how genre and register theory (GRT) can deepen our understanding of text organization, Dalton-Puffer (2013; 2016) offered a heuristic to operationalize the teaching of text-in-context by way of a construct called "Cognitive Discourse Functions" (CDFs), which utilizes verbal actions, modeling cognitive strategies, to represent language. In line with genre-based approaches, Dalton-Puffer (2013) defines CDFs as "patterns which have crystallized in response to recurrent situative demands in a context where participants have recurrent purposes for communicating" (p.231), which in science are realized in recognizable patterns for *defining, classifying, describing, evaluating, explaining, exploring,* and *reporting*. The aim, according to Dalton-Puffer (2013; 2016) is to link subject-specific cognitive learning goals (such as *defining*) with the linguistic representations the students are exposed to and expected to produces (e.g., *allele is versions of the same gene at the same place on a chromosome*). The author proposed that such an approach is capable of equipping CBI/CLIL teachers with dual qualifications in teaching language and content in an integrated manner. By the same token, in 2016, Lin proposed the "Genre Egg", a metalanguage to provide an "accessible common vocabulary for both content specialists and language specialists" to work together to help learners analyze academic texts in disciplinary areas. This analytical framework integrates the top-down and bottom-up approaches of teaching language where vocabulary, sentence patterns, academic functions, academic text types and curriculum context can be viewed as text-in-context (bottom-up) or as the overall linguistics choices made to mobilize purpose (top-down). Lin (2016) argues that although a top-down approach is essential for a deeper, more holistic path to acquiring literacy and criticality, students who are also learners of the language of the medium need to be explicitly taught vocabulary and the structure of lexico-grammatical patterns (bottom-up) to be able to utilize them in understanding and formulating language functions, such as *defining, classifying exemplifying, contrasting*, etc. The earlier example of *defining* alleles, according to the Genre Egg, would follow a formula for definition-giving: technical term + relating verb + general class + phrase/clause giving defining details. (Lin, 2016, p. 42). I will use this formula in my data analysis to illustrate how to scaffold the registers of scientific language.

Teaching vocabulary, according to the Genre Egg, takes the form of identifying three word families: technical vocabulary, general academic vocabulary, and linking words so that learners can "master the variations in language patterning (or linguistic features) in different contexts" (Lin, 2016, p. 19), and the team of teachers can modify the text for simplification or enrichment based on the learners' needs. Nevertheless, such a grammar-based approach does not dictate isolated vignettes of grammar lessons; the Genre Egg integrates focus-on-form with the process of content learning in such a way that learners can find the attention to language functions authentic, meaningful and relevant to the context in which they are situated. Overall, the Genre Egg has been identified as an important element to raise teachers' awareness of academic language in CBI/CLIL settings. I will take advantage of this framework in analyzing my data to make sense of my level of awareness to teaching language based on lexico-grammar, register and genre.

As SFL centres around language functions, context occupies a central place in this discussion, i.e. it focuses on how language both acts upon and is constrained by its meaning enacted in a social setting. In this light, SFL views language as "a semiotic tool, that interacts with social context in making meaning" (Schleppegrell, 2004, p. 18), which resonates with my view of CBI to extend critical engagement with texts via a link to real-world curricula especially global problems which have social and scientific solutions. Other, more recent, SFL-informed pedagogical heuristics show promise in critical literacy teaching in science. For instance, Fang, Adams, Gresser, & Li (2019) use SFL to teach a unit on climate change, moving beyond grammar-based text analysis of SFL to instead develop students' understanding of the ways various genres present information, structure texts and infuse judgement to engage audience. Thus, the teaching of the language of science needs to teach academic genres and registers explicitly to offer ELLs access to the dominant ways while acknowledging *all* students' familiar and home languages as legitimate and valuable to equip learners with linguistic competence and counter linguistic hierarchies.

2.2.3 Inquiry-based Approaches in CBI

With the help from the findings of genre-based research in teaching language in content, the last decade in CBI has observed a different trend (Early & Kendrick, 2017; Hume, Cooper, & Borowski, 2019; Lee, Quinn, & Valdes, 2013; Walsh, 2011; Weinburgh et al., 2014; Wu & Lin, 2019): a movement away from sheltered instruction to language-in-use, as well as a movement away from teaching discreet language skills to supporting language development in the appropriate contexts and experiences; and lastly, a movement away from native competency toward operating between different languages and cultures in becoming functional users of multi languages (Douglas Fir Group, 2016). An example of this movement is teaching inquiry-based, evidence and argument-driven debates and knowledge-based reasoning in science while teachers monitor, scaffold and situate individual students' language use to ensure all are comprehending discourse and participating in it (Chin & Malhotra, 2002; Duff, 2002; Early & Kendrick, 2017; Lee et al., 2013; Pica, 2008; Zeilder, Herman, & Sadler, 2019). Martin (2000) defines inquiry skills as a set of broadly transferable abilities, reflective of the behavior of scientists, such as describing, defining, interpreting, hypothesizing and experimenting. Martin claims that appropriate skills in learning such actions can promote science literacy for all students and especially for language learner students. Other researchers in SLA highlight the importance of context for inquiry pedagogy to be successful; they believe that the key to inquiry-driven teaching is to provide the appropriate context for authentic language use while participants are engaged in the process of meaning making (Lee et al., 2006; Stoddart et al., 2002).

The support for inquiry-driven pedagogy in CBI comes from sociocultural theories which view student learning as positioned through social activity in context where learners become active agents in their own learning (Derewianka, 1990). Sociocultural theories place emphasis on the means of communication, such as language, to display a strong link between one's position in social activities and the cognition and mental activities of individuals because collaboration and peer-to-peer talk are a natural part of meaning making (Gomez Zwiep & Straits, 2017). Thus, intellectual social connections playing out in authentic social environments such as classrooms, where language mediates learning and internalization, provide the ground work for inquiry-based learning in science where higher order thinking can develop (de Oliveira et al., 2019; Lee et al., 2013; Stoddart et al., 2002; Weinburgh et al., 2014). Furthermore, sociocultural theories support inquiry-based teaching in science in culturally, linguistically and cognitively meaningful and relevant contexts (Bunch, 2013). For science learning to involve authentic inquiry, making a link between the cultures of the home and the classroom becomes important especially when there are incongruences between students' background knowledge and schools' expectations. Lee et al. (2006) highlight the importance of developing congruence between students' cultural and linguistic experiences and the specific demands of science as a discipline in teaching the language of science and helping students maintain cultural identity. Therefore, teachers need to draw on various linguistic, conceptual and cultural resources for designing scientific inquiry where there is content and language integration. In the next section, I will offer a review of research studies with the objective to design inquiry-based lessons and tasks while integrating language and content in their curricula.

2.2.3.1 Studies in inquiry-driven teaching

There is a wealth of research which supports inquiry-based or inquiry-informed teaching in CBI. ELL students, especially in high schools due to the pressure and urgency of acquiring sufficient academic literacy for graduation requirements, often do not encounter the same rich and hands-on learning experiences in adapted science when compared with English language students in mainstream science. Learning experiences, such as designing and carrying out experiments, participating in engineering design tasks, investigating ecological footprint projects; and overall, working on extended and meaningful projects are commonly non-existent when adapted science is taught by language teachers or when the science teacher has to address the language of instruction also as the object of instruction in an already tight syllabus to which they need to adhere (Durán, 2008; Fry, 2007, 2008). Over the last decade, researchers have urged initiatives which blend inquiry-based science and language development in increasingly learner-centred teaching environments (Early & Kendrick, 2017; Lee et al., 2013; Lyster & Ballinger, 2011; Oliveira & Weinburgh, 2017; Seglem & Garcia, 2018; Stoddart et al., 2002; Weinburgh & Silva, 2010; Weinburgh et al., 2014). In their recent book, "Science teacher preparation in content-based second language acquisition", Oliveira and Weinburgh (2017) draw from a myriad of studies to establish that CBI teachers need to expand science teaching by departing from English vocabulary learning as the only method in teaching science. The authors advocate for inquiry-based science by stating that "open approaches to science teaching such as inquiry-based science education demand students to use a diversity of language modalities, registers, and genres in order to be able to model natural phenomena" (p. 301).

Much attention has been given to the importance of multimodalities within the multiliteracy pedagogy to teach inquiry-based science (New London Group, 1996) where learners' home practices of language and culture are recognized as rich resources; however, disparities in socioeconomic status within language-minority learners is worthy of attention and research (Early & Kendrick, 2017; Early, Dagenais, & Carr, 2017). When investigating the impact of an inquiry-based instructional model on linguistically and culturally diverse group of elementary students, Lee et al (2006) found that inquiry science provided a learning environment where collaboration, peer-to-peer talk, and the hands-on nature of inquiry lowered the linguistic burden for students while they engaged in meaning making naturally. In another article, Weinburgh et al. (2014) showed that when engaging ELLs in one grade 8 science class in inquiry-based learning, while maintaining a "business as usual approach" in the control class, increased levels of science content knowledge and academic vocabulary were observed in the experimental group compared to the control group. Lastly, Mercuri and Mercuri (2019) proposed that approaching CBI in science with both refugee and immigrant groups, using an inquiry-based learning organized around an interdisciplinary unit, invited facilitation of higher levels of literacy development and acquisition of academic vocabulary simultaneously. The list of studies echoing the integration of scientific inquiry and language teaching to promote higher-order thinking in both science and literacy is significant.

The instructional format of promoting greater interaction among students, and between teacher and student, models “science discourse patterns” such as providing evidence, offering rationale, conducting procedures in inquiry and critically designing hypotheses (Stoddart, Tolbert, Solis, & Bravo, 2010, p.14). This format of instruction and close negotiation allows for “epistemic types of questions and commentary that are highly restricted for [English learners] in classrooms where yes and no, closed type of questions dominate classroom talk” (Bunch, 2013, p. 318). In a three-year long study, Gomez Zwiep and Straits (2017) invited 60 elementary schools to participate in teaching an integrated science inquiry and language development program through a 5E (Engage, Explore, Explain, Elaborate, and Evaluation) model. The results showed that the blended lesson designs focusing on creating collaborative opportunities for the learners to discuss and debate ideas through scientific inquiry and investigation resulted in successful learning outcomes. The study cautioned that teachers’ language scaffolding needs to be carefully crafted and supportive of students’ authentic inquiry by not interfering with student thinking and talking even if imperfect in form.

To sum up, inquiry, not in the sense of exploration with the eventual means of resorting to a unilateral, dominant and established view, but in the way of exploration leading to enhancing skills to question and to make connections for individual leaners is the authentic and effective pedagogy discussed in the studies above which have shown positive learning gains. As a result, the focus of much research currently is on the kinds of inquiry learning which promote reasoning, evaluation and argumentation in science classrooms. This next section will examine this kind of teaching approach.

2.2.3.2 Inquiry via argument-driven, knowledge-based reasoning in CBI

The second half of the twentieth century has demanded inquiry-based science to make use of a diversity of language modalities since describing, questioning, comparing, justifying and argumentation, are all employed in defining natural phenomena. A wealth of research (see Chinn & Malhotra, 2002; Duschl & Osborne, 2002; Eruran & Jiménez-Aleixandre, 2007; Khine, 2012; Zeidler & Sadler, 2007) has generated knowledge to suggest that learners in the discipline of science should be exposed to procedural and strategic learning in order to be equipped with the “abilities to reason and reflect metacognitively on their own learning and the construction and evaluation of scientific knowledge” (Duschl & Osborne, 2002, p. 39). In order to do so, the authors proposed that teachers need to focus on how evidence is used in science to construct explanations and how those explanations are evaluated. I see much resemblance between these criteria and the criteria used to teach students how to successfully debate scientific issues where reasoning, justification, argumentation and evaluation come into play. However, in CBI, not only teaching the pragmatics of debating but also the semantic of the discourse become crucial wherein ELLs can utilize language tools to engage in argumentation, construction of explanations, evaluation of evidence and responding to opposing views. Below, I will report on two empirical studies which examined an argument-driven inquiry (ADI) as a pedagogy in science teaching. The first portrays such a pedagogy in mainstream science and the second depicts the added layer of language teaching intertwined with ADI in a CBI setting.

Science educators have been noting the importance of language and social interactions in the use of scientific argumentation (as the process of constructing an argument) to solve problems in conceptual change, reasoning and knowledge building among students (see Khine, 2012). Duschl and Osborne (2002) reviewed the language genre of argumentation in relation to the functions language, conversation and discourse hold to, first, define what constitutes argumentation in science education, and, second, to highlight classroom conditions that promote and nurture argumentation practices successfully among students. The authors ascertain that “argumentation is fundamentally a dialogic event” (Duschl & Osborne, 2002, p. 55) where plural accounts need to replace singular explanations of phenomena. They listed a series of socially-related science issues wherein not only the orthodoxy of scientific principles but also misconceptions, everyday laymen terms and controversial opinions would serve to foster perspective-taking, critical thinking, deep connections, and knowledge-based reasoning. This review paper concluded that inquiry-based learning was at the heart of teaching the art of argumentation as peer-to-peer interaction is where learners can legitimately and confidently question and test their newly-formed ideas in light of power relationships that inhibit learners from engaging in debate with a classroom teacher.

In a CBI setting, awareness of such power relationships is even more crucial. Many learners in adapted science classrooms come from educational backgrounds where the authoritarian nature of science education and the teacher has been embedded in their life experiences. To encourage and empower this group of students to question the conventional ways and the dominant cultures of power become an important responsibility of the teacher via classroom discourse. Argument-driven inquiry (ADI) was proposed in 2019 by Callahan, Sampson and Rivale, as a solution to investigate a pedagogical strategy which guides learners in CBI to exploration and discovery as opposed to delivery of information in a top-down approach. To start a scientific inquiry, teachers in the study asked learners: *what they know, how they know it,* and *how to communicate it with others.* The research on ADI proposed an instructional model of eight stages where learners were asked to produce spoken and written accounts of their experiences while receiving peer evaluations, editing and implementing laboratory observations and experimentations in their revised work. While students were being guided to participate in scientific practices, ADI teachers provided opportunities for them to learn how to use academic forms of language in the context of science to "figure things out" as opposed to "learn about" things. Language-intensive instructional approaches in conjunction with ADI have the potential to help develop science writing in light of viewing multilingualism as a resource to bolster ELLs scientific self-efficacy. In this way, the authors claimed, teachers can disrupt the status quo and demand that learners decide for themselves where the value of science lies.

But, ADI alone cannot diminish the inequities present in educational systems and eliminate the English divide; what it does, is promise to shift discourse by inviting learners to engage in science processes of inquiry dialogically and critically. In rhetorical and discourse analysis, teacher-led activities have been observed to dominate the discourse following an initiation-response-evaluation pattern (Osborne, 2001; Mortimer & Scott, 2003; Scott et al., 2006). In such a context, learning *about* science but not *doing* science is privileged. Therefore, the discourse of classroom interactions in which language and content intertwine becomes the space for teaching the pragmatics and the semantics of science as well as the art of reasoning and argumentation. A closer look at classroom discourse will take place in the next section, where I will discuss a framework designed to analyze shifts in classroom interactional discourse to the benefit of students' conceptual gains in science.

2.3 Communicative Approach Framework

2.3.1 Introducing the Framework

To study how discourse becomes part of the social practice of the science classroom, Lemke (1990) argues that discourse, seen as differentiated speech depending on subject matter and varying from everyday language to technical, is introduced to learners in the science classroom via text and people. How to build connections across the differentiated speech forms, from everyday language to disciplinary genres, has been a topic of much interest. Mortimer and Scott (2003) constructed an analytical framework to examine the discourse of classroom talk and classroom interactions along the content spectrum moving from everyday to disciplinary/technical based on tensions between dialogic and authoritative communicative approaches and shifts in interactive and non-interactive talk. With over ten years of classroom observation and research in schools in England and Brazil, the authors analyzed countless hours of classroom interactions between teachers and students and among peers delving into conceptually-demanding scientific topics, scientific principles, investigating essential causes of chemical reactions, physical properties of matter and theorizing of the particle model. Through the discrepancies between the everyday and technical discourses revealed in classroom interactions, learning demands became evident to the researchers, and the "scientific story"- as Mortimer and Scott (2003, p. 106) described it- began to develop. The "scientific story" or scientific point of view, borrowed from Ogborn, Kress, Martins, and McGillicuddy (1996) by Mortimer and Scott, offered an account or a kind of story to unpack the complexity of a given science concept within familiar natural phenomena using the ideas and conventions of the school science social language. The authors argued that in telling a story, "talk" became central to the "meaning making" process and to learning (Mortimer & Scott, 2003, p.6). In their book, *Meaning Making in Secondary Science Classrooms*, (2003), the authors differentiated *dialogic* and *authoritative* discursive classroom interactions (which I will define later in this section) and concluded that the meaningful understanding of scientific conceptual knowledge cannot take place if both types of discourses are not present.

In an equally successful empirical study, Scott et al. (2006) replicated the previous study and conducted research at a middle school in Brazil investigating some basic concepts of thermal physics. The classroom teacher introduced each experiment with a preliminary presentation to contextualize the problem and to locate it within the developing science story. Students worked in small groups to perform an experiment, discuss their observations and report the findings. The data confirmed Mortimer & Scott's earlier findings in that dialogic and authoritative approaches were intimately connected and a tension existed between the two. Scott et al. (2006) proceeded further by highlighting the implications of the study for science teachers by concluding that teachers need to have a strong knowledge base to "engage fluently in dialogic interaction with students" (p. 623). The work of these scholars formed the backbone of my dissertation both in the construct of the communicative approach framework and in the insight that they offer on the knowledge base of teachers in order to successfully engage students in discursive interactions. Both topics will be reviewed more fully in the remaining parts of section 2.3.

The communicative approach framework, or CA framework as I will refer to it, is based on a sociocultural perspective of teaching and learning drawn from Vygotskian principles where human learning is theorized to be a social process and social interactions believed to develop cognition. Since science teaching and learning occur through the talk of the science lesson (Mortimer & Scott, 2003), talk becomes central to the meaning making process and central to learning through introducing students to the scientific views and supporting their meaning making especially when conflict arises in integrating old and new science ideas or in integrating one's own and others' ideas. As meaning making is a dialogic process either in exchanges with others or in one's reflections (Bakhtin, 1981), ideas and viewpoints come in tension and need to be worked upon. In the CA framework, this type of tensioned rhythm within classroom discourse is studied in relation to five aspects of a lesson: 1) purpose, 2) content, 3) communicative approach, 4) discourse patterns of interaction, and 5) interventions. Below, I will give examples from the book, *Meaning Making in Secondary Science Classrooms*, (2003), for each of the five aspects in terms of the questions one asks to arrive at defining these aspects of a science lesson:

1. What *purpose* is served in each teaching episode? Teaching *purposes* range from opening up the problem, exploring and working on students' views, introducing and developing the scientific story, guiding students to work with science meaning and supporting internalization, guiding students to apply and expand on the use of

science view, to lastly maintaining the development of the science story.

2. What is the nature of the *content* discussed in each teaching episode? Is content everyday or scientific? Descriptive, explanatory, or generalized? Empirical or theoretical?

3. What *communicative approach* does the teacher use to interact with the students? The CA framework defines four approaches as follows: Dialogic/Interactive, Dialogic/Non-Interactive, Authoritative/Interactive, and Authoritative/Non-interactive. A more detailed description of what each approach encompasses will be offered in the next section.

4. What *discourse patterns of interaction* emerge between teacher and students? These patterns of interaction include two types: triadic IRE (Initiation, Response and Evaluation), and the chain IRF (Initiation, Response and Feedback) in repetition with no evaluation.

5. What pedagogical *interventions* are available to the teacher? The interventions range from shaping ideas, selecting ideas, marking ideas, sharing ideas, checking student understanding, to reviewing.

In short, the CA framework is an analytical tool in understanding classroom interactive discourses by tracking the rhythm of the shift in interaction from dialogic to authoritative communicative approaches and vice versa. Before I discuss the application of such a framework to CBI, I will briefly introduce the theoretical background on which the framework is based.

2.3.2 Bakhtin and Communicative Discourses in the CA Framework

The CA framework, drawing on Bakhtin's work, was constructed to analyze the speech genres of classroom interactions which are in actuality composed of multiple and many dialogues or, at times, a single dialogue. According to Bakhtin, all language use is dialogic and language/discourse is realized in the form of concrete utterances with every utterance responding to previous utterances and anticipating future responses. *Dialogism* in the sense characterized by Mikhail Bakhtin (1986) informs and is repeatedly informed by others' utterances or work. *Dialogue* as defined by Bakhtin entails an utterance responding to a previous utterance or utterances; and in this sense, even discourses presenting a single viewpoint and commonly classified as "authoritative" must also be dialogic. The distinction between *authoritative* and *dialogic* discourses for Bakhtin lies in the rigidity of authoritative discourses, not in the absence of an interlocutor or the absence of other viewpoints. Once space is made available for the rigidity to soften, Bakhtin claims that a state of gradual appropriation of meaning where new ideas are half one's own and half belonging to 'others' will evolve. The full appropriation of ideas will result in the internally persuasive discourse or *internalization* as Mortimer and Scott refer to it. According to Lantolf (2007), *internalization* permits transformation of something that was once guided by others to be independently operating.

In essence, Bakhtin (1981) entertains the idea of "interanimation" to refer to an internally persuasive discourse as coming into contact with other's utterances, which differs from how Mortimer and Scott treat it as a true consideration of others' views. In Bakhtin's conceptualization, "internally persuasive" (1981) discourse is a dialogic discourse in which the power lies within the individual cognition, growth, criticality and eventual persuasion. In Bakhtin's definition (1986) any utterance will be received and worked towards the potential to be internally persuasive- even the authoritative utterances. Mortimer and Scott, although accepting the dialogic nature of any and all discourses, adhere to a definition of an authoritative discourse as established by the absence of the consideration of multiple viewpoints highlighting its rigidity.

2.3.3 Mortimer and Scott's Critical Lens

As mentioned in the above section, within Mortimer and Scott's CA framework, dialogic and authoritative discourses are distinguished on the basis of how strongly the points of views of others are considered. In a dialogic discourse, the meanings and points of views of the students, such as their everyday views of scientific concepts, are considered- albeit to varying degrees of interanimation. For instance, a low level of interanimation of ideas depicts teaching where the teacher listens to students' ideas but the ideas are not reflected in the course of a lesson and/or the exchange of ideas is not the goal of the lesson. In contrast, a high level of interanimation of ideas would resemble a classroom where the teacher allows students' ideas to develop and be reflected in the direction, content and goal of the day's lesson. If much negotiation of ideas in the form of dialogues, exchanges, questions and answers is present in the course of the lesson, Mortimer and Scott label this approach an *interactive dialogic* discourse. However, if the teacher presents multiple views - in other words, students' or others' views - in the talk of the lesson without much interaction with the students themselves, the discourse is labeled *non-interactive dialogic*.

On the other hand, in the authoritative discourse, the teacher's purpose is to introduce and establish only one meaning (often the scientific view) and others' meanings and views are not considered. In this communicative approach, although the classroom teacher may allow for different voices to be heard and hence create an *interactive authoritative* discourse, only those ideas which are aligned with the teacher's lesson objectives are considered. Therefore, there is no level of interanimation of ideas present as only a single idea or perspective (again, the disciplinary norm) is acknowledged. If teaching is authoritative and utterances are made by one individual, likely the teacher, this approach is labeled as *non-interactive, authoritative*. In sum, four types of communicative approach within Mortimer and Scott's framework exist: interactive/dialogic, non-interactive/dialogic, interactive/authoritative, and non-interactive/authoritative.

Mortimer and Scott (2003) and Scott et al. (2006) argue that there is a need for both of the dialogic and authoritative communicative approaches in the teaching of the discipline of science. They ascertain that bringing awareness to the students of the presence of multiple perspectives and the need for criticality cannot come about if teachers do not model the dialogic discourse where others' perspectives are heard, respected and considered. This allows learners to begin the social process of building agency and "enlarging their already heterogeneous cultural views" (Mortimer & Scott, 2003, p. 106). Similarly, if the talk of the social plane of the classroom is restricted to authoritative discourses, especially in a non-explorative manner, then the students will internalize that as the "principle way of *thinking* about science" (p. 116). This is why creating a dialogic social discourse through the talk of the lesson to build the scientific story is crucial to the core of any science teaching practice. So, what purpose does the authoritative communicative approach serve? Imagine a science classroom where the social language of science is taught through dialogic discourse patterns of instruction in the absence of any authoritative interjections. Students engage in argument-driven inquiry and develop reasoning skills in the absence of a rigorous knowledge-base. Teaching and learning performance continue to implement an explorative design but where does the learner access the scientific point of view and the disciplinary knowledge-base to reason? Mortimer and Scott (2003, p.106) ascertain that students will not "stumble upon" or find the path to discovery of the key principles if somewhere within classroom interactions an authoritative interjection and introduction of the key concepts are not offered. Thus, the shift from one communicative approach to the other plays an essential role in the rhythm of the classroom set by the teacher and her knowledge of the social language of science.

Discourse of the classroom involves teachers' discourse moves: pedagogical action and language scaffolding performed by the science teacher flexibly and naturally as new language emerges in the talk of the lesson (de Oliveira et al., 2019). To link Mortimer and Scott's CA framework developed in the science classroom to analyzing interactional discourse with language learners in CBI, I needed to add a language pedagogy lens to my literature review. Section 2.4 of this chapter will review the knowledge base of teachers in designing their language pedagogy and in their awareness of the role of the language in classroom discourse.

2.4 Teacher Knowledge

2.4.1 Introducing the Field

The purpose of this part of my literature review chapter is to first present what the literature proposes as the relevant and the recommended knowledge base to the teachers working in my field, and second, to outline how I could use this knowledge in order to analyze my pedagogical practices from my data to ascertain the impact of my practice and my knowledge on classroom discourse and learning gains.

It is common sense that all teachers need to have knowledge of the subject matter- a good grasp of the content area. In terms of the academic content of the school disciplines, teachers need *Content Knowledge (CK).* This is knowledge of the core ideas of the specific discipline, a rich conceptual understanding of theories, and principles that are taught in the content area aside from skills, such as teaching how to read certain genres, write for different purposes, or conduct research which students also need alongside learning content. Shulman (1987) identified a different knowledge base: *pedagogical content knowledge (PCK),* knowledge of the delivery of the content; i.e., the skillful transfer of content knowledge to leaners not for them to merely absorb the knowledge but also to lead to enhanced student understanding. PCK is an understanding of how specialists teach their various disciplines including: subject matter cognition, knowledge of context, knowledge of curriculum, and knowledge of pedagogy.

In other words, PCK is knowledge of content as well as knowledge of pedagogy. To enable learners to use discourse that characterizes the academic domains of the content area, teaching the specific academic literacy of the subject is necessary. This not only includes learning the specific vocabulary and terminology of the subject matter, but understanding how to read, write, evaluate, reason and debate in particular ways specific to the content area (de Oliveira et al., 2019; García, 2009; García & Godina, 2004). Such learning of academic literacy and content knowledge is more challenging for those learning the language of content area and the language of instruction simultaneously and it demands special and nuanced skills on the part of the teacher. The next section will discuss the knowledge base of CBI teachers.

2.4.2 Knowledge-base for CBI Teachers

When teaching content subjects through the medium of the learner's additional language being developed or acquired simultaneously in the content classroom, the classroom teacher needs to have a more specialized knowledge base- one that goes beyond knowledge of the content and knowledge of the pedagogy, one that addresses increased language and literacy expectations across the curriculum. Galguera calls this more nuanced knowledge base, *pedagogical language knowledge (PLK):* "purposefully enacting opportunities for the development of language and literacy in and through teaching the core curricular content" (2011, p. 298). It is important not to mistake PLK with *pedagogical content knowledge about language* which is needed by language teachers specialized in teaching ELLs. PLK can be viewed as knowledge of language of the content area related to disciplinary teaching and learning within the particular contexts of the classroom. Bunch (2013) supports Galguera's notion of PLK by suggesting that teachers in content subject areas whose students are also language learners need not only PCK but also knowledge about the language of the discipline for which they are responsible. This knowledge about the language of the discipline is what is broadly labeled as PLK.

How do teachers gain PLK? Drawing from the field of SFL proposed by Halliday (1994), to gain PLK is to learn to analyze language features, such as grammatical features of content-area text, as the central part of the knowledge base for teaching language in content. When meaning and form are intimately related to one another, grammar becomes a functional meaning-making tool to convey different modes of communication in relation to the specific social context. SFL does not stop at mere language features of text, it bridges the text features with purposes they fulfill. Therefore, the relationship between form and function will be illuminated for the students via text analysis and will equip them to decipher which linguistic choices influence or are influenced by the different purposes in a social setting. In a similar vein, other scholars agree on viewing language knowledge beyond a technical and analytical perspective. Some take on a sociocultural perspective in viewing language knowledge in the role that it plays in "participation in academic practices" (Bunch, 2013). Here, the focus is on language as a resource for participation and this is the lens that teachers need when viewing PLK. In this view, as Johnson (2009) states, "meaning resides not in the grammar of the language, or in its vocabulary, or in the head of an individual, but in the everyday activities that individuals engage in" (p. 44). Thus, it is not the structural properties of language that convey conceptual meanings expressed via language, but the social aspect of language as a social practice contextualized and situated in different ways of being. In this regard, a discussion of the critical perspectives in CBI/CLIL studies becomes pertinent.

2.4.3 Critical Perspectives on the Knowledge-base for CBI Teachers

CBI as an instrument in furthering not only academic attainment but also student participation, fostering learner independence, and increasing cognitive, social and emotional competencies, can also offer a critical lens to educators. Although not the main focus in my research, critical perspectives which involve a reflective critique of the imbalance of power in society and the changes needed to empower people (Giroux, 1983), cannot be ignored in any research examining teaching and learning, which involves relations of power. In 2000, Cummins proposed a critical perspective on the "hidden curriculum" (p. 546) in language teaching which encompassed three components: focus on meaning, focus on language and focus on use. The author ascertained that in this trio dynamic, the educator is offered choices in how meaning, language and the user are being positioned and positioning others. Cummins suggested that attending to these aspects in language instruction allows for the enactment of a "transformative pedagogy" (p. 539) with the goal to contribute to student empowerment to the extent where the student explores critically why one form of language is considered higher status, how language can be used authentically, and how a culture of inquiry can be nurtured. Another grass-root pedagogy in CBI views CBI as founded upon societal needs, and thus, capable of maintaining its connection with society. Critical CBI or CCBI, proposed by Sato, Hasegawa, Kumagai, & Kamiyoshi (2017) maintains that the connection between CBI and society has been diminished and only when language users become active agents to acquire as well as to analyze and evaluate the knowledge they've been exposed to, such connection can be enhanced.

Similarly, Galguera (2011) drew from Fairclough (1999) and van Lier (1995) to highlight the importance of "critical language awareness" in gaining PLK which needs to be taught to pre-service teachers through language-related knowledge bases in a way that language awareness is not seen as limited to English language proficiency coupled with pedagogical skills, but broadened to an awareness of factors such as multilingualism and its relationship to English. García (2017) extends this critical view further to propose "critical multilingual awareness" as CLIL and CBI teachers' abilities to challenge dominant ideologies of language and discourse when arbitrary privilege is given to certain languages inhibiting students from participating in equitable language practices (Lindahl, 2020). The integration of content and language as a social practice within studies examining critical (multilingual) language awareness formed the core of a special issue in which a number of studies contested and negotiated their own interpretations of this integration (Darvin, Lo, & Lin, 2020). This special issue explicates the greater societal power positions as key players in determining content and language designs, curricula, teacher roles, language mediation, and institutional factors. Thus, the message conveyed urges those involved in programs founded on CBI or CLIL to examine them critically, opening up the spaces to invite fluidity of interpretations and expectations, and plurality of languages and practices. To widen one's horizon in viewing teachers' language awareness critically is crucial because these views will inadvertently impact pedagogical decisions in the classroom as I will explain next.

2.4.4 The Construct of TLA

One challenge for CBI teachers is that the medium of instruction is also one of the objects of instruction. Therefore, instruction that leaves language out of the classroom discussions or that teaches grammatical features in isolation will not be fruitful. According to Andrews (2007), to truly intertwine abilities- that is to teach language and to shelter content- teachers need awareness of language in relation with text, context and learners. Andrews (2007) defines this type of awareness of language as *Teacher Language Awareness (TLA)* which holds a level of empathy for and understanding of ELLs' academic needs in compelling teachers to acquire the appropriate pedagogical tools and instructional strategies for teaching language (Andrews, 2003).

Rooted in CLIL studies, TLA has wide application in CBI. Andrews and Lin (2017) make a vivid case as to why TLA is such an important construct when they differentiate between "using" language and "teaching" language in this manner:

> The key to understanding [integration of language and content] is to differentiate between *using* subject-specific language to teach content on the one hand, and *teaching* subject-specific language to talk about content on the other (p.67, italic in original).

Here, the teacher takes on the roles of language user, language teacher and language analyst. In this sense, the dilemma of adapted content courses being taught by either the language teacher or the content teacher can be partially resolved. Using the three roles TLA carves out, the content teacher will not use academic language of the subject-matter without analyzing it and the language teacher will not only analyze and teach the language of the subject-matter, but also use it in the appropriate context. Thereby raising teachers' awareness of language would also translate into raising their analytical awareness to be able to perform contrastive text analysis of academic language features. This notion brings SFL back into the discussion of how to teach TLA to preservice and in-service teachers and how to tie it into enacting curriculum in CBI. As Andrews and Lin (2017) advocate, awareness of genres of the particular disciplinary registers according to the genre and register theory (GRT) (Halliday & Hasan, 1976; Rose & Martin, 2012 in Andrews & Lin, 2017) can add an analytic skill to the toolkit of teaching pedagogy and in turn, expand CBI teachers' roles into user, teacher and analyst.

Similar to PLK, TLA is also embedded in the larger sociocultural context as classrooms cannot be conceived as unproblematic and fixed settings; they are organic, constantly-changing and dependent on learner, teacher and greater societal structures. Context is also intertwined with the notion of teacher cognition as it encompasses teachers' beliefs and attitudes towards the subject matter situated in context. Teacher's language-related cognition becomes a key player which Andrews and Lin (2017) describe as teacher's views of language which encompass their feelings and beliefs. According to Tsui (2003), the situated nature of cognition in TLA allows for the teacher to make pedagogical decisions that fit the needs of the learners situated in a real classroom in any given moment. Therefore, some dimension of TLA is experiential and grows out of the challenges encountered in the classroom in relation to language; and some, as Galguera (2011) stated, should be implemented in language-related, knowledge-based programs for teacher education.

2.4.5 TLA in Practice

Andrews and Lin (2017) describe interrelated knowledge bases that make up TLA: knowledge of the language of the discipline and how it functions in isolation; and knowledge of how it functions in and through pedagogical practice. These two dimensions of TLA can promote the language awareness of teachers at the intersection of content, language and pedagogy. Drawing on TLA (Andrews, 2007) as a heuristic, I can analyze my TLA in classroom interactions in relation with learning outcomes and patterns of communicative discourse.

TLA as an analytical tool can be synthesized into tangible components to measure high versus low levels of TLA. Based on a view of teacher as language user, language analyst and language teacher, these components are written in terms of teacher abilities or pedagogical competence materialized in successfully facilitating a lesson, transferring knowledge, defining gaps, and assessing needs. The synthesizing components are divided into three categories of what TLA looks like during 1) lesson preparation, 2) lesson facilitation, and 3) impromptu or "just-in-time support" as introduced earlier (Oliveira & Weinburgh, 2019). Below, I am referring to the examples suggested by Andrews and Lin (2017, p. 61) in measuring high levels of TLA.

In the context of lesson preparation, TLA impacts the teacher's ability to:

1. analyze target language from the perspective of the learner/learning
2. identify key features for learning
3. highlight those features appropriately in examples to be presented to learners
4. specify appropriate learning objectives
5. select material and tasks that suit the learners and serve those objectives

Within the classroom itself and once the lesson begins, TLA affects the teacher's ability to:

1. provide appropriate language-related mediation/scaffolding
2. help learners notice key features in language that is made available for learning
3. produce spontaneous examples and appropriately-formulated clarifications
4. monitor the language produced by students
5. limit potential sources of learner confusion

The teacher needs to meet the 'real time' challenge of responding spontaneously or impromptu to language learning opportunities as they arise which requires:

1. alertness and quick thinking on the part of the teacher
2. ease of access to the subject-matter knowledge base
3. a good level of communicative language ability
4. constant awareness of the learner

In the study design chapter of my dissertation, I will discuss how I can make use of the TLA components listed here to analyze my content knowledge, pedagogical knowledge, language awareness, planning and preparation abilities, and appropriate use of materials to demonstrate the link between high and low levels of TLA and the rhythm of classroom discourse; and whether this type of awareness impacted the rhythm of the classroom discourse and the necessary language accommodation moves I used with my students.

2.5 Identity and Empowerment

It is impossible to do classroom research without considering issues of identity when the objective is to learn from a teacher's journey and transformations in acquiring new awareness and knowledge and the impact of that knowledge in helping students gain both academic literacy and criticality in understanding academic hierarchies and systemic power relations. Although my research is not specifically inquiring into identity work, I do need to consider how my teaching helped empower my students as legitimate science learners and science doers, which is closely intertwined with issues of identity. Hence, in this section, I will make use of literature on identity to bring forward perspectives that have been instrumental in illuminating CBI teacher identity. As well, I will make use of studies where the end goal has been to afford learners confidence and empowerment through acquiring competencies (in section 2.5.2). Whether this has organically developed or was pedagogically fostered in my study, I will highlight the links and associations to make sense of how my students grew to become competent users of the genre of classroom science discourse to find a confident voice to question, reason and negotiate science. The breakdown of this section will involve two parts: 1) teacher identity and agency and 2) student competence and empowerment.

2.5.1 Teacher Identity and Agency

Teacher identity proves to be a critical component in the sociocultural and sociopolitical landscape of the language classroom (Kubota, 2001; Norton, 1997; Pennycook, 2001) in terms of the teacher's "positionality in relation to her students, and to the broader context in which the teacher is situated" (Varghese, Morgan, Jonston, & Jonson, 2005, p. 22). In TESOL, the issues of social marginalization, power relations between native speaker and non-native speaker teachers, the complex status of World English and the colonial legacy of a 'native speaker fallacy' (Canagarajah, 1999) all impact classroom teaching and teachers' lives.

Language teacher identity has been the topic of much research recently as it is found to be a key player on how teaching and pedagogy materialize in the classroom (Tsui, 2007; Varghese et al., 2005; Varghese, Motha, Park, Reeves, & Trent, 2016). In a study examining the issue of identity among student teachers of TESOL, Ilieva (2010) found that adopting and internalizing authoritative discourses without problematizing them, impacted the complex nature of these student teachers' identity construction. In De Costa and Norton (2017), language teaching is presented as identity work where a transdisciplinary framework enables us to deepen our understanding of language teacher identity amidst changing multilingual and globalized worlds as highlighted in the work of the Douglas Fir Group in 2016. The transdisciplinary framework allows for an understanding of teachers as agentive professionals where classroom Discourse (Gee, 1996) in terms of language policies, relations of power interwoven in the genres and registers of the curricula, and the hidden agendas of greater institutions become exposed and available to the teacher to use as a teaching tool. Therefore, teachers through exercising their agency can enact their professional identities in meaningful ways to enhance not only the learning outcomes of their students but also students' self-confidence, their access to opportunities and their involvement in designing their futures in the workplace (De Costa & Norton, 2017; Ilieva & Ravindran, 2018).

When discussing science teacher identity, disciplinary affiliations and the privileges embedded in them, teachers' subject knowledge as well as social markers of ethnicity and gender play key roles according to the existing literature. In 1998, Helms wrote an article: "Science – and me: Subject matter and identity in secondary school science teachers" and drew from multiple sources to explore science teacher identity. In this article, many scholars collectively expressed that subject affiliation is a powerful component of professional community, particularly for the academic subjects. Certain academic fields (such as science), enjoy a higher status owing to their association with the university, and often a broad professional community outside of academia. Status also stems from the academic background of the teachers, the rigor of the high school curricula, and the perceived quality of the enrolled students.

CBI teacher identity formation is unique resulting from CBI teachers' ongoing and somewhat mandatory collegial, interdisciplinary collaborations, subject affiliations, TLA and PCK, as well as emotional experiences. Lyster and Ballinger (2011) report on studies where, in spite of the pairing up of a subject-matter specialist with an ESL specialist in the same classroom, institutional and wider societal agendas make equitable integration of content and language challenging by weighing language with less status, inadvertently jeopardizing students' learning outcomes and opportunities for them to question and experience curricula as authentic, relevant and student and inquiry-driven. In another study by Pappa, Moate, Ruohotie,-Lyhty, and Eltelapelto (2017) examining the notion of teacher identity in CLIL, it was recognized that "agency" as a lens was used in the ways pedagogical, professional and relational teacher identities were negotiated. According to Ilieva and Ravindran (2018), "professional identities are linked within space and time through reflective self-awareness of the possibilities for agentive action in professional contexts" (p.7*).* In other words, there is a cycle where change in one will bring an ongoing and cyclical metamorphosis onto both agency and identity. For example, a teacher's classroom practice and interaction with students can challenge ingrained views of dichotomies of identity as "native vs. non-native", "male vs. female" and "science vs. language".

Teaching an inquiry-driven, CBI-inspired, adapted science class as a female, Iranian-Canadian, bi-lingual, Science and TESOL-trained teacher-researcher, the “hyphen” became the place in which my experience was situated. The lens of a content and language teacher, the lens of a Farsi and an English speaker, the lens of a teacher and a researcher, and the lens of a classroom expert and authority as well as a minority, English-as-a-second-language speaker (an identity engraved deeply within me) played important roles in shaping this research and interpreting its findings. Hence, the dichotomies of the many spectra that I navigated within allowed me to build my research design within the structures of educational research in this practitioner inquiry but also enabled me to do so critically and reflectively.

As identity can be an analytical lens for making sense of a teacher’s views of self, situated in context, it can also be used as a tool to make sense of teacher transformation and teacher knowledge awareness (Morgan, 2002; Simon, 1995; Varghese, Morgan, Johnston, & Johnson, 2005). Using the identity theories discussed above as a backdrop, I aim to reflect on my role in relation to my students and my colleagues as they view me in terms of my non-nativeness and my ongoing negotiation of discursive positioning and being positioned as a language and science teacher in an adapted program in a secondary school. The hyphenated identities offer space for understanding my lens as a teacher in designing the curriculum and my lens as a researcher in analyzing the discursive interactions with curriculum and with my students. Therefore, although my research analysis does not dwell on issues of teacher identity or student identity or reveal the challenges of interdisciplinary collaboration and disciplinary status, my transformation and changes in my awareness of what was required to make this journey successful are juxtaposed against identity construction, due to which issues of identity cannot be ignored.

While CBI advocates integration of content and language, based on sound theoretical and pedagogical principles, the field has not yet understood the demands on teachers in making this marriage work, as well as the extent to which constructing a harmonious content *and* language teacher identity may be attainable. Morton (2016) investigated the relationship between teacher cognitions, identities and classroom practices in relation to the integration of content and language. Morton points out that most researchers such as Cammarata and Tedick (2012) and Baecher, Farnsworth, and Ediger (2014) draw on Shulman’s (1987) construct of pedagogical content knowledge

(PCK) and express that CBI and Immersion teachers lack the necessary language knowledge to effectively integrate language objectives with content teaching. In fact, they argue that research has uncovered only a partial understanding of what knowledges are necessary for teachers to materialize such an integration. This notion resonates with my research objective to examine TLA, PCK and awareness of what knowledge I was equipped with and what was missing during the making and the implementation of my lessons to be able to teach confidently. The transformation in my awareness is intractably linked to my teacher identity and my agency to empower my students by giving them a voice, teaching them critical thinking, reasoning and argumentation skills.

2.5.2 Student Competence and Empowerment

Broader educational agendas go beyond literacy skills to also support students' social-emotional competencies. Research has suggested that as students develop competence and motivation, they demonstrate pride, engage in collaborative projects, contribute to problem-solving situations, and take control of their own lives (see Greenberg & Harris, 2011; Jennings & Greenberg, 2009; Kuhn, 1993; 1999). As social-emotional competence helps achieve positive identities and foster academic growth (see Cummins & Early, 2015; Darvin & Norton, 2015; Norton & Toohey, 2011), it is important to understand what pedagogical and epistemological teacher beliefs can maximize students' potential to build such competencies towards greater social empowerment in their futures. The BC Ministry of Education website in outlining the New Curriculum for K-12 defines school-related competencies as follows:

> The Core Competencies are sets of intellectual, personal, and social and emotional proficiencies that all students need in order to engage in deep, lifelong learning. Along with literacy and numeracy foundations, they are central to British Columbia's K-12 curriculum and assessment system and directly support students in their growth as educated citizens. (BC Curriculum, 2021)

Furthermore, the ministry defines personal and social competency as a set of abilities that relate to student identity and help them achieve their purposes in the world. The ministry suggests that students develop core competencies when they are engaged in the "doing" within a learning area, which stresses the roles student-driven and inquiry-based teaching play in this endeavor. Overall, it is found that school-based programs promoting students' social and emotional competence foster resilience and confidence. The question I ask is: how are such competencies supported?

In a comprehensive research review in 1997, Wang, Haertel, and Walberg found that among the most significant categories of influences on learning, most involved social and emotional factors (e.g., student–teacher social interactions, classroom climate, and peer group). As a result of their work, "psychological determinants of learning" became a key player in ensuring that effective learning took place among all students in schools. Closely linked to the concept of identity (Belcher & Connor, 2001; Cummins, 2000; Danielson & Warwick, 2014; Darvin & Norton, 2015; Morgan, 2004) as well as content learning (Jennings & Greenberg, 2009; Varelas, Martin, & Kane, 2012; Zins & Elias, 2006) CBI studies provide a suitable space to research pedagogical strategies supporting social-emotional competency. Content learning in CBI and identity construction are linked by way of involving meaning making (Varelas et al., 2012). In this theorizing, the authors (ibid) proposed three intersecting identities when examining visible minority students in science programs: disciplinary identity (the science doer), racial identity (what it means to be a visible minority), and academic identity (as participants in academic tasks) (ibid, p. 319). Learning as a sociocultural activity curtails building meaning via interactions, access to ideas and information, and positioning within a community of practice (Wenger, 1998). Therefore, Varelas et al. (2012) ascertained that students do identity work (meaning making in the overlap of the three emerging identities) in conjunction with learning the content of a discipline which manifests itself in classroom participation, engagement, supporting each other and acquiring subject matter knowledge. In the discussion of my data, I will aim to gain a better understanding of how the students developed disciplinary and academic identities, as delineated by Varelas et al. (2012), while participating in learning tasks. Questions of students' racial identities which required that I interview them and conduct more intimate question and answer sessions did not fit the scope of my research.

Research on social and emotional learning (SEL) by Greenberg, Weissberg, O'Brien, Zins, Fredericks, Resnik, Elias in 2003, endorsed a reform model of competence enhancement among youth in US schools. Successful, school-based intervention programs were found to promote social and emotional competence in youth where programs encompassed the following three epistemological approaches: 1) coordinate school-level organization and planning, 2) create a caring learning climate, and 3) strengthen teacher instructional practices (Greenberg et al., 2003, p. 468). Although the premise of the study was based on helping at-risk-youth through using the resources of the extended community, the findings can transfer to understanding competence enhancement in youth from non-dominant cultures acquiring academic literacy in a foreign language in Canadian high schools. In the same spirit, Cumming and Lyster (2016) found that teaching language in content resulted in the students' expressions of success and confidence. In interviewing the students involved in a research project learning French and Science concurrently, the study participants felt the task at hand gradually became easier with time and offered to them dual benefits in content and language learning. Initially, students' psychological barriers, such as frustration, anxiety and lack of confidence in the task, presented challenges; however, as the unit progressed, the students became more familiar with the interventions and the routines which resulted in making substantial progress. The connection between academic achievement and attainment of social and emotional skills is key. In a study of SEL, students' social and emotional competence measured via leadership, social skills, and study skills were assessed against their academic performance. The participants who received the intervention displayed higher year-end grades compared to those who were in the comparison group (Reyes, Brackett, Rivers, Elbertson, & Salovey, 2010).

In CLIL studies, issues of anxiety were also linked to learning outcomes where lowering foreign language speaking anxiety was correlated with enhanced literacy skills (Dalton-Puffer, 2011). By the same token, in CLIL settings, increasing interest and subject content relevance have been found to correlate with student motivation (Banegas, 2013; Coyle, Hood, & Marsh, 2010). In a two-year CLIL study with 50 students aged 15-19 years in a school in Colombia, Garzón-Díaz (2021) found that integrating a cultural component into teaching environmental sciences while the participants are learning English promoted the students' sense of scientific citizenship. The learners expressed building models and working in groups as positive, enjoyable and motivating aspects of learning. In science, the idea of "scientific citizenship" (Gibbs, 2015), a relation between science and society, has been the eventual aim of many programs. The three dimensions of scientific citizenship defined by Gibbs (2015) conceptualized as membership, rights and participation make it possible to see classroom activity as essential in enacting a science identity. The behavior and roles of students in science classes as the investigator, observer, analyst, reporter, biologist, geologist, etc. can more fluidly approximate the identity of a science-doer or science-knower. Garzón-Díaz (2021) argued that as the study participants became more engaged in the project, they displayed empowerment to make their voices heard, adopted a stance in relation to the environmental issues, and felt confident to defend their standpoints with evidence-based arguments. How students' multiple experiences, perspectives, languages, cultures and identities in CBI allow for access to scientific citizenship will need to be vastly researched. In the discussion chapter, I will draw from my data to shed light on "scientific citizenship" to the extent that it was materialized in the interactive classroom talk.

The adoption of roles as an indication of identity building was also documented by Kendrick, Early & Chemjor (2019) examining how youth in informal learning environments acquired media literacy. The authors noted the roles of explorer, participant-user, performer, and activist within the social practices performed by the participants during the data collection period (p. 124). Most significantly, the role of an activist was found to show strong links with building confidence by enabling the participants to "gain access to new social context, perform new identities, become socially active and demonstrate new levels of competence in the design of multimodal text" (ibid, p. 134). The role of an activist is founded on reasoning, evaluating and argumentation skills, which are foundational in scientific argumentation. Kuhn (1993) classified a type of learning competency as "argumentative competency" which she defined as commonalities in the argumentative strategies people bring to make sense of scientific and other matters (Kuhn, 2010). Utilizing the everyday argumentative and debate competencies of high school students as a design in argument-focused school science curricula, Bricker and Bell (2012) found that collaborative debate offered space for the learners to develop their social and cognitive competencies to do critical thinking, refining their supporting ideas, offering intellectual work, coordinating theory with evidence, displaying creativity, and guiding teachers in their curriculum design. This kind of data has a central place in the interpretation of my findings particularly in engaging the students in debate and scientific argumentation.

In summary, the interactions between students, teachers, and the curriculum become key players in students' academic achievement, and thus, internalized feelings of success or failure. These interactions offer spaces for negotiation of identities where the science student may experience the role of expert in the discourse of science and the role of novice in the discourse of language. Hence, it is crucial as educators to support the ongoing construction of students' identities to produce multicompetent learners. The literature reviewed in this section suggests that social-emotional competence and academic achievement are interwoven and integrated. Supporting competence building for students, whether under the umbrella of school-related core competencies, personal competency, social-emotional competencies, or argumentative competency contribute to a strong sense of empowerment, positive identity construction, engagement, and collaboration with others. My aim in analyzing my data will be to investigate the areas of integration between learning outcomes and competency development for my students within teacher-student discursive interactions.

2.6 Gaps in the Literature

I will identify five areas of gaps in the literature which I have reviewed in this chapter. First, minority students learning non-linguistic curricular content in schools via a language medium foreign to them, lack equal access to the valued linguistic and curricular knowledge capital (Bunch, 2013; Janzen, 2008; Lin, 2016; Von Esch & Kavanagh, 2017). Much research has been generated in elementary schools, but there is a dearth of knowledge in understanding the types of challenges high school teachers face in teaching senior level Science, Math and Social Studies in order to meet the needs of ELLs (Garcia, 2009; Pawan & Craig, 2011). One such challenge is offering rigorous curricular content in adapted science; content that is relevant, authentic and uncompromising, which can only come about when students of diverse language backgrounds are viewed as being equipped with many and multi competencies as opposed to having a deficiency that needs to be fixed. The perspective of "multi-competence" (Cook, 2008) was generated in response to the "deficit lens" which viewed the language skills of an "L2 user" as irrelevant and inferior. Through the multicompetency lens, these diverse languages and backgrounds are no longer held against those of a native speaker's but viewed as greater than the sum of the languages used by the individual. The second challenge is possessing high levels of TLA which translates into understanding the genre and register theories as well as the lexicogrammatical patterns of the language of the discipline for content teachers. The third challenge lies in that research shows great potential for language learning during science instruction; however, what a language-focused, content-centred, inquiry-based science lesson in high school looks like in order to achieve this potential has not been researched widely (Olivier & Weinburgh, 2017; Mercuri & Mercuri, 2019; Wu et al., 2018). My aim is to address this need by constructing curricula according to the mandates expected of mainstream science teachers in BC and implementing the lessons in high school adapted science using inquiry-based activities and CBI pedagogical strategies.

Second, despite a wealth of research that demonstrates the benefits of dialogic discourse in the classroom, such as genuine scaffolding, activating students' prior knowledge, utilizing learners' funds of knowledge, and teaching reasoning and argumentation skills, there is a limited body of evidence to suggest that shifts in the rhythm of the communicative discourse to employ dialogic interactions while teaching the disciplinary conventions can have a positive impact on measured student-learning outcomes in relation to science concepts (Leach, Ametller, Lewis, & Scott, 2005; Scott et al., 2006). I plan on addressing this gap in the context of an adapted science program where the rhythm of the classroom discourse is being juxtaposed against student learning gains both in conceptual and language areas. I will apply the analytical frameworks I discussed in the literature review in this chapter in making sense of classroom interactions with the potential to highlight the benefits of the necessary shifts in discourse.

Third, as Baecher, Farnsworth, and Ediger (2014) state, when the medium of instruction is also the object of instruction with the added layer of content teaching, clear content area objectives with specific language foci become inherently crucial. The technical aspects of when and how to make language accommodation moves on the part of the teacher, without interrupting the flow of classroom talk, as well as how to articulate language objectives to students without giving away the answer to their science inquiries are presently the topic of much research and investigation (eg, Lin, 2016; Oliveira & Weinburgh, 2017; Settlage, Madsen, & Rustad, 2005; Weinburgh et al., 2014). It is suggested that raising the content awareness of language teachers and the language awareness of content teachers is a feasible way forward in addressing the needs of ELLs in content courses (Andrews & Lin, 2017; Lin, 2016; Wu & Lin, 2019). I will reflect on the knowledge needed to accomplish this task and offer some recommendations for teacher training programs. It is obvious that we cannot assume automatic ability to convert TLA knowledge into pedagogical skills in ways to design clear objectives and teaching purposes for students with special and diverse needs. The process of assessing the linguistic demands of content-area material to adapt discourse and the necessary teacher knowledge and awareness to do so will be highlighted in my research.

Fourth, Lin and Lo (2017), in the context of English as a foreign language in CLIL classrooms in Hong Kong, express that teachers are confronted with a number of constraints, “including the dual challenge of teaching content and L2, gaps in students’ L2 proficiency, as well as a tight syllabus in an exam-driven culture” (p. 42). Other educators claim that the language teacher in CBI is faced with the job of sheltering content while assessing linguistic demands of content-area materials, making the material available to the learners via adaptations, and setting language objectives. A job this ambitious and under time constraints more often than not forces teachers to forgo language objectives and teach content only (Baecher et al, 2014; Bigelow & Schwarz, 2010; Fisher & Frey, 2010). What constraints will I face in this journey of designing and delivering a specialized curriculum to meet language and content objectives for high school students from diverse language backgrounds and varying levels of proficiency in English? My research can help shed light on the challenges of this journey in the absence of interdisciplinary collaboration and support. While my professional background afforded me experience and skills in teaching both English to speakers of other languages (ESOL) and secondary level science, most teachers in adapted settings are either content teachers or English language teachers. I hope to highlight the challenges of developing and implementing an integrated curriculum of language and content and in the final chapter of my dissertation to return to the topic of interdisciplinary collaborations and reflect on how my journey would have developed differently if I had initiated and sustained meaningful cooperation for team planning and team teaching between my department and the Language Arts department at the school to address the challenge of fulfilling both language and content objectives given the existing time constraints.

Finally, juxtaposing ADI in an adapted science class, researchers ascertain that argumentation must be dialogic (Duschl & Osborne, 2002, p. 55) where plural accounts relating ideas and their evidence need to replace singular explanations of phenomena. Other scholars in the field claim that without this critical understanding, CBI runs the risk of perpetuating rather than disrupting existing inequalities and marginalization (Callahan et al., 2019; Kubota & Lin, 2009). Although authoritative discourse does not function well when the goal of instruction is to promote reasoning skills because the teacher, rather than the student asks the questions, which ensures that the conditions of inquiry are restricted and controlled by the teacher and hence not student-driven, I believe invitation of plural accounts alone will not foster successful ADI. In my view, teaching the orthodoxy of scientific principles to foster perspective-taking, deep connections, and knowledge-based reasoning are essential in making debates and argumentation rigorous and content-based. If plural accounts and dialogicity in the absence of data and facts were the only means of cultivating reasoning and debate, argumentation and evaluation would not be knowledge-based. I argue that teaching ADI in CBI needs to occur at the intersection of debate and knowledge of the established norms and scientific perspectives. As a relatively up and coming topic in SLA, there is a wealth of knowledge that can be generated via classroom interactional discourse analysis to understand the nuances of argumentation and debate within science-based language instruction.

2.7 Summary and Research Questions

While the integrated approach of simultaneous content and language teaching has been proven effective, it is not without its challenges. CBI planning and teaching is a complex pedagogical endeavor where developing content objectives in science as well as language purposes have been reported by pre-service teachers to be demanding of enormous skills (Baecher, Farnsworth & Ediger, 2014; Fisher & Frey, 2010). The demands that this type of teaching places on educators to acquire the knowledge of the content-area registers are significant. As the pertinent literature was reviewed in this chapter, to be able to competently teach the genre of science discourse, classroom teachers must explicitly teach certain communicative practices, such as those used in making claims, evaluating evidence, reporting results and representing scientific principles. A growing number of teacher educators are using the theoretical and pedagogical tools of SFL to support teachers' TLA by viewing the knowledge of language as integral to teachers' content knowledge for teaching (Accurso, Gebhard, & Selden, 2016; Lin, 2016; Moore, Schleppegrell & Palincsar, 2018; Rose, 2015; Rose & Martin, 2012; Zhang, 2017).

I aim to examine how a teacher can skillfully navigate pedagogical strategies to shift between attending to language forms and attending to conceptual content while co-constructing knowledge with the learners situated in context. My study addresses pedagogy through the lens of classroom discourse and TLA in adapted science with the potential to advance knowledge for teachers in similar settings as well as to assist ELLs in high schools where graduation and later-on access to workplace opportunities are an uphill battle (Bunch, 2013; Cummins, Mirza & Stille, 2012; de Oliveira et al., 2019; García, 2009; Gunderson, 2007; Janzen, 2008; National Research Council, 2017; Toohey & Derwing, 2008). The rationale for this study was to bring insight into the expansive knowledge that is needed for teachers of CBI to foster language development, reasoning skills and understanding of science concepts.

My research has the potential to advocate for high school students from non-dominant languages to become legitimate participants of a science community (Lave & Wegner, 1991) and to simultaneously access language capital (Bourdieu, 1977). I have chosen to take a thin slice of this topic in the field of applied linguistics to engage in the following broad, overarching *research inquiry*: how might an inquiry-driven pedagogy unfold in a CBI science class and what can we learn from this process in relation to 1) classroom discourse, 2) English language learners' educational outcomes in terms of academic literacy, and 3) teacher language awareness? I use my *research inquiry* to derive finer and more practical *research questions* as listed below:

1. How do classroom interactional discourses in one adapted science classroom influence learning gains and knowledge-based reasoning skills?

2. How does TLA enacting language accommodation strategies impact the rhythm of classroom discourse and students' learning gains?

3. How can a CBI teacher raise the students' awareness of disciplinary language features and conceptual content features, and how does this help the learners develop criticality, confidence and a positive science learner identity?

4. What are the challenges of a teacher-researcher's study in designing and delivering inquiry-driven lessons for English learners in high school adapted science?

The ultimate goal of my research on classroom discourse in adapted science is to contribute to Cummins's definition of a *transformative pedagogy* as "a form of critical literacy where [students] become capable of not only decoding words, but also reading between the lines in order to understand how power is exercised through various forms of discourse" (Cummins, 2000, p.46). I also hope to contribute to a grass-root pedagogy with the potential to enhance capacities to teach knowledge that empowers learners by diminishing the language divide and the achievement gap. Such critical pedagogy has the promise to put the C before CBI in what Sato et al. (2017) call *Critical CBI* (CCBI) which claims that teaching of language in conjunction with content needs to invite "critical engagement with texts and reflection on self and others via open dialogues about various social issues" (p. 64) if connection between CBI and society is going to be maintained. In pursuit of critical studies in CBI, I keep these critical and nuanced perspectives in mind as I interpret my classroom interactions with my students, my language accommodation moves to make content accessible while keeping it rigorous and globally conscious, and my teacher language awareness and its impact on classroom discourse in order to shed light on ways to engage in CCBI.

Chapter 3. Research Design

3.1 Introduction to My Research Methodology

A methodological approach, or research strategy, is defined by the relationship between one's research focus and the social theory or phenomenon being studied. As Denzin and Lincoln (2018) state, "Methodology is inevitably interwoven with and emerges from the nature of particular disciplines (such as sociology and psychology)" (p.231). The basic assumption is that all mental actions, such as learning science and language, are inevitably situated in cultural, historical and institutional settings and what is accepted as knowledge of teaching and learning in school science is clearly related to these settings (Mortimer & Scott, 2003). From the sociocultural perspective, language is a social practice which takes place in context; and the classroom teacher needs to have knowledge of language as a semiotic tool and a meaning-making system (Johnson, 2009; Lantolf & Beckett, 2009). In this view, classrooms are treated as dynamic and complex social systems where attention is paid to the role of language as a social practice in authentic learning situations (Hawkins, 2004). My choice of research methodology as *classroom research* will be explained and justified in section 3.2, where I will discuss classroom research in language education and how my study resonated with the methods described as classroom research among a myriad of other existing methodologies.

3.1.1 Ontological Stance

One's research draws on the researcher's ontological and epistemological stances. According to Denzin and Lincoln (2018, p.210): "Ontology raises basic questions about the nature of reality and the nature of the human being in the world." According to Mason (2018, p.4), knowing that there are alternative "versions" of the nature or essence of "social things" allows the researcher to find his or her position in relation to the phenomena or essence of inquiry. In my research, the essence of inquiry is the role of pedagogy within discursive interactions in the classroom to enhance student learning. With this in mind, I see the social world I'm investigating as the interactions occurring in the classroom. To define reality within those interactions, I take a relativist stance conforming to the paradigm of constructivism: "realities are perceived, multiple and exist in people's minds and therefore, socially co-constructed" (Paltridge & Phakiti, 2015, p.17). In this sense, I see my research question as ontologically meaningful as I believe learners and discourse are key components of classroom life in the way learners engage with discourse and in the way it is made available to them: to interrogate, to problematize, and to utilize. Therefore, I don't view learners as receivers but as co-constructors of realities in participation with teachers; this allows the portrayal of classroom reality as multiple, participative, interactive, situational, contextual and socially constructed.

3.1.2 Epistemological Stance

According to Denzin and Lincoln (2018), epistemology asks, "how do I know the world?" and "What is the relationship between the inquirer and the known?" (p. 210). The *constructivist* and *participatory* epistemologies (Denzin & Lincoln, 2005; 2018; Guba & Lincoln, 1994) inform my research in the sense that they endorse the primacy of practical, community-based and participatory knowledge where meaning exists in the mind and in interaction with the world but must be enacted by human participation before it exists in actuality. What Guba and Lincoln (1989) put forward regarding a *constructivist* epistemology is that knowledge is true only when it is consented by the community to be true. *Participatory* epistemology adds another dimension to principles that determine what is knowledge. In *participatory* epistemology, knowledge becomes experiential and dependent on the linguistic and conceptual context of the community through critical subjectivity where, "[o]ur personal knowing is always set within a context of both linguist-cultural and experiential shared meaning, having critical consciousness about our knowing necessarily includes shared experience, dialogue, feedback, and exchange with others" (Heron & Reason, 1997, p.283). For my research questions, this explains the essence of bringing discourse under analysis to understand the nuances of dialogue, feedback, exchange and consideration of viewpoints of "others". Also, to return to Heron and Reason's participatory paradigm of viewing ourselves as co-inhabitants of the planet, curriculum needs to mesh with the natural world and ecological urgencies that need our future generation's awareness and preparedness. Hence, in curriculum design, I aimed to paint a "big picture" for all the conceptual, theoretical, and technical understandings to tie in with urgent environmental and climate crises.

Consequently, my epistemological stance in line with my ontological framework is *participatory* which portrays reality as participative, co-created by mind and given cosmos (Denzin & Lincoln, 2018). The *participatory* paradigm engages with a subjective-objective reality which is described by Heron and Reason (1997) as follows:

> [To] touch, see, or hear something or someone does not tell us either about our self all on its own or about a being out there all on its own. It tells us about a being in a state of interrelation and co-presence with us. Our subjectivity feels the participation of what is there and is illuminated by it. (p.279)

My relationship with knowledge that can emerge from my research resonates closely with my participation in my research as a teacher, inquirer, explorer, practitioner and researcher. My research findings emerge in context of the community and in discursive interactions with my students, who are co-creators of knowledge, while course curricula examine global environmental issues which have a social and ethical dimension.

3.1.3 Subjectivity

As a researcher's biases, values, prior experiences and knowledge permeate into the epistemology of her research, articulating one's subjectivity becomes a key component of good research practice. My subjectivity stems from my role as a bicultural and bilingual teacher of science and CBI in diverse SLA settings and from my ethnicity as a minority in my place of work, which I have discussed briefly in the context of literature examining issues of identity. Due to my experiences of learning English in adolescence, I identify with my ELL students in their academic, social and emotional growth. I hold schools accountable for shortchanging students of curricula that is rigorous, authentic, critical, inquiry-based and argument-driven to empower language learners with knowledge-based reasoning. I see linguistic capital as essential in their journey through the challenges of acquiring academic literacy and multicompetencies in preparation for the global communities of work in which they will participate.

Tsui (2007) identifies the following factors that influence teachers' subjectivity of teaching and learning: their personal background and life experiences, their disciplinary training, their teaching and learning experiences, and their teacher education. Furthermore, Cochran-Smith (2012) claim that decades of critique and analysis have shown that research is never divorced from politics, perspectives, subjectivities, and funding opportunities; and it is this nuanced view of research that the novice researcher needs to maintain in order to build a research agenda that is ethical and meaningful. I believe my subjectivity has much to do with viewing the foundations of SLA and CBI in North America as problematic as they were largely built on a pervasive deficit model (Cazden, 2011; Gonzalez, 2005; Hull & Schultz, 2002) which as I raised earlier, assumed an epistemological stance of language diversity as a deficit as opposed to an asset, and language and literacy practices of minority students as insufficient in equipping them with knowledge and skills. (Cazden, 2001; Cook, 1999; Lin, 2016). This is an epistemological perspective positioning the home cultures of minority students as inadequate and multilinguilism and multiculturalism as insignificant. I am aware of this view and hope to find space in my research to exhibit how this does not need to be so. Adapted programs with a deficit approach cannot foster the critical engagement necessary for students to design their social futures and achieve success through fulfilling employment (Cope & Kalantzis, 2000; 2016). I plan on designing an adapted program which *does* foster learners' critical engagement through acknowledgement and engagement of their funds of knowledge and diverse experiences.

Subjectivity within a participatory epistemology framework presents us, humans, as knowers and as such, my knowledge of self and professional identity have come from my subjective experiences in relation with my students in the classroom, my colleagues, my identity as a non-native speaker of English, and a non-native teacher of English in senior level Science. Another layer that permeates into the epistemology of my research is my hyphenated identity of a language and science teacher which affords me a lens unique in a sense that I can view the challenges and the triumphs of designing and implementing CBI curricula from the perspectives of both language and content teachers. I believe the duality in knowledge and experience could offer insight on where and how adapted teaching benefits from interdisciplinary collaborations.

3.1.4 Participant Perspectives

The participatory paradigm relies heavily on collaborative forms of action inquiry where "To experience anything is to participate in it, and to participate is both to mold and to encounter" (Heron & Reason, 1997, p. 283). Thus, participation is necessary to establish democratic dialogue among researcher and study participants - me and my students, here viewed as "collaborators" – merely in the sense that respecting and validating students' prior and new knowledge and their insights delineate my epistemological perspectives. Students' voices and their views shaped my research design and accorded the students not only the label of "participants" but also "collaborators". This form of inquiry rests on the principles of "epistemic participation" which ensures that new knowledge is grounded solely in the experiential knowledge of all participants, collaborators and co-researchers. Hence, although, the participants did not design the research methods or partake in the analysis of the data, their input in the form of learning outcomes influenced my methodology along the way. Students' prior knowledge and their experiences were key elements in molding and constructing new knowledge and my designed activities.

3.2 Classroom Research in Language Education

There are many examples of qualitative methodologies in language education used by teacher researchers in their own classrooms. *Classroom research* (Breen, 1985; Toohey, 1988)*, teacher/practitioner research/inquiry* (Borg, 2013; Cochran-Smith, 2012)*,* and *(participatory) action research* (Hagevik, Aydeniz, & Rowell, 2012) have become familiar terms in recent Applied Linguistics literature on research methodologies (Mason, 1996). However, they are often used interchangeably; consequently, the distinctions have become unclear. Bailey (2001) comments that "[action research] is sometimes confused with teacher research and classroom research because in our field, action research is often conducted by teachers in language classrooms" (p. 490). However, each of these orientations to research denote a specific focus: *classroom research* aims to understand the dynamics of a classroom, *teacher research* is any research conducted by teachers, *action research* refers to a methodology which is specific to address the teaching-learning process in the classroom for teachers to identify problems, seek existing knowledge, collect data, implement strategies for change, and prepare for a new cycle of improvement. To best identify my research paradigm, I have chosen *teacher research* as an umbrella term and *classroom research* as the more nuanced method.

Teacher research (Cochran-Smith & Lytle, 1990), a constructivist approach, is defined as research conducted by practitioners in their own context and for the purpose of developing their understanding of their practices (Borg, 2013). It "encourages teachers to reflect on their practice, and therefore leads to potential change. It plays an important part in reflective teaching, where personal and professional development occur when teachers review their experience in a systematic way" (Field, 1997, p.192). Paltridge and Phakiti (2015) claim that *teacher research* allows teachers and learners to disclose perceptions of their educational experiences which can be powerful and instructive. According to Duff (2007), such power in *teacher research* is possible since participants from diverse educational or cultural backgrounds can make interpretations in relation to their knowledge or the activities at hand that differ from those of the established norms and standards. When teachers become integrally involved in the many aspects of their research process - from the planning stages to the interpretation of the results - deeply-rooted, conventional practices of the greater institutions can be problematized and examined critically.

What distinguishes *teacher research* from *classroom research* (Breen, 1985; Duff, 2007; Toohey, 1998; 2000) is that *teacher research* does not always center on the classroom; whereas, *classroom research* is primarily conducted by academic researchers whose studies relate to questions of classroom teaching and learning. Although traditionally conducted via "experiments" in language laboratory settings (Breen, 1985) for the testing of theoretical hypotheses, the last several decades are revealing a greater number of exploratory and descriptive studies located in natural classroom settings (Cummins & Davison, 2007). Duff (2007) ascertains that there are thematic patterns in how *classroom research* is conducted. First, the focus is on a narrative account of students' behavior, activity, knowledge, and/or written products; second, the teacher is observed during the same activities in which the students were engaged; third, the observations are videotaped or audiotaped; fourth, discourse is analyzed during activities of interest; and fifth, potential follow-up interviews with participants often occur.

As a teacher-researcher, *classroom research* resonates with the components I used to conduct my research, despite the absence of follow-up interviews and my own self-reflective journal. Both, inquiry and practice, carried out by researcher and teacher respectively can form a "symbiotic relationship" to benefit the outcomes (Cochran-Smith, 2012). In such an integrated role, not just answering but also posing questions in investigating my own practice and assumptions, *classroom research* offers space for inquiry and reflection where I can ask what knowledge and awareness I needed in this journey of creation and implementation of a specialized curriculum to be successful. I can do so when I observe and analyze my role as the classroom *teacher* by adopting the role of an *analyst*. With the aim to understand the potential of the communicative interactions within classroom discourse, the required teacher knowledge, and the aim to improve the learners' lives, collecting and analyzing data via *classroom research* can lead to genuine change, empowerment of linguistically and culturally diverse learners, and recommendations offered to teacher training institutions.

3.3 Gaining Access to My Research Site

In designing my research study to collect data, I needed to gain access to an adapted high school science class for which I would create teaching material, teach, record and analyze my data. I used my network of past co-workers. A friend who had taken on the role of an ELL consultant at the Vancouver School Board, put me in touch with her colleague in West Vancouver School District (WVSD) who operated as the English language enrichment program coordinator and had a close connection with the science department in one school. But first, I needed to obtain SFU's ethics approval and WVSD's permission to approach the science department with my proposal. Following ethics approvals, the ELL program coordinator at WVSD reviewed my documents and connected me with the Science department head who discussed with me the possibility of one of his teachers in an Adapted Science 10 classroom welcoming my project. With a few email exchanges and one in person meeting with Jim (a pseudonym), it was decided that upon the students' consent, I could come into his adapted science 10 class, to observe, to teach, and to record for as many classes as I needed to. It was decided that I would teach the units of Genetics and Earth Science over two three-month long semesters, while Jim would take the responsibility of teaching Chemistry, his area of expertise. This was not very good news to me, as I was trained in teaching Chemistry but a stranger to Earth Science. I accepted nevertheless. Jim let me know that he had no experience teaching an adapted science class as he had just been offered this position. He had taught for many years in a school district where almost the entire student population consists of monolingual English speakers and had never interacted with or taught an ELL student. After three classroom observations during Jim's facilitation of lessons, I got to work.

I explained my consent letters to the students and sent the letters home via the students. All the letters came back signed by parents or home-stay families. I was ready to collect data. I conducted a pre-study, informal focus group interview to inquire on the students' views of adapted courses versus mainstream classes. The results showed that generally, the learners had a positive view of the adapted setting and felt optimistic about their academic goals becoming realized with the language support offered simultaneously.

3.4 Participants

My participants were fourteen science 10 students whose ages ranged from 15 to 17 years of age. Six of the students were female and eight were male. The educational backgrounds of the students ranged from zero to two years of schooling in Canada, and their English language proficiency ranged from developing to fluent. Eight of the students had come to Canada from Mainland China, three from Iran, two from Japan and one from Italy. One student was learning disabled but there were no gaps in the formal schooling of any of the participants. The survey I gave to the participants showed that science was taught in their home schools every year of their education. In this sense, every student was placed in their appropriate grade level, with the exception of two of the students who would have been in grade 11 in their home countries but were doing grade 10 Adapted Science. The Adapted program was a solution that this particular high school had designed as a transitional or sheltered syllabus for those students who were assessed and designated as English language learner. This group of students was also enrolled in Adapted Social Studies and Adapted Language Arts. All these adapted courses were taught by the respective mainstream content classroom teachers and only adapted in that the syllabus was to enrich language learning while the content followed the ministry's grade 10 core competencies and prescribed learning outcomes. The students were to continue enrollment in the Adapted program for one year, exit and merge into regular grade 11 courses. There was no formal grading involved in the adapted classes as report cards evaluated skill-building and competencies. The Adapted program teacher coordinator would assess students' English proficiency level by the end of grade 10, permitting them to exit the transitional courses.

3.5 Study Design

I designed lessons keeping in mind BC's New Curriculum core competencies which encompass sets of "intellectual, personal, social and emotional proficiencies" (BC's Curriculum, 2016). The curriculum also adopts a concept-based approach where active engagement of students for deeper and more transferable learning is key. The ministry website sets out facets of the core competencies to make suggestions for student learning via inquiry, creating and carrying out plans, synthesizing information, reflecting on reasoned conclusions, and critical thinking activities. Hence, my lessons were designed based on each unit's prescribed learning outcomes while I aimed to integrate inquiry-based learning, knowledge-based critical reasoning as well as concept-based competency in order to address my research objectives. I needed to be cautious that I considered learners' needs in both language and content while fulfilling promises of expanding their literacy skills to conduct inquiry, to ask critical questions and to offer knowledge-based reasoning for their findings. To ensure that inquiry was at the heart of each activity, the lessons began by posing a question, allowing students to draw from their prior knowledge, devise a plan of action in researching and collaborating, and finally reasoning and communicating their findings. Next, I needed to consider the types of data useful to me and the methods of data collection in my research approach.

3.5.1 Research Approach and Procedures

Denzin and Lincoln (2018) paint a picture of the ontological stance of data residing on two ends of a spectrum: data as "lifeless", waiting to be processed or data as having "power and agency" in controlling access to knowledge (pp. 825-830). The interpretation of data is largely dependent on the design of the research that first and foremost needs to reflect the theoretical conceptualization of the study, which in itself is linked to the phenomenon under examination. To return to the research paradigm in this section of the chapter is very relevant.

Constructivist paradigm adopts a non-experimental, non-manipulative, and hermeneutic set of research procedures including techniques associated with participant observation and in-depth interviews. The term hermeneutics is used to describe a research process in which the researcher forms interpretations or constructions from an understanding of data (Denzin & Lincoln, 2018). In collecting data in a natural setting and viewing it in an interpretive manner, I believe that data maintains power and agency. To participate in the research as the teacher/researcher, I was able to take advantage of a classroom as the natural setting. Considering the different dimensions of language, in content teaching and learning, exploration takes place not in isolation but in context and goes beyond purely achievement measurements. In this regard, *classroom research* guided me to bring the intricacies of classroom dynamics into perspective with teacher and students' lives in the classroom as the focus of inquiry: what shapes the many layers of classroom discourse, what dimensions of pedagogical knowledge were required and acquired, and what defines success in the delivery of lessons, and what is powerful to all participants in knowledge-based reasoning.

3.5.2 Data Collection Methods

To follow the thread of a naturalistic and interpretive approach to research, qualitative data collection methods consist of "interpretive, material practices that make the world visible. These practices turn the world into a series of representations, including field notes, interviews, conversations, photographs, recordings, and memos to the self" (Denzin & Lincoln, 2018, p. 46). Taking the epistemological aspect of my research into consideration when examining research in English language and content teaching, immersing one in the environment allows for deeper insight into the minds and perspectives of the participants (Paltridge and Phakiti, 2015). And this is precisely what I aimed for in my research: a deeper insight into the discursive interactions during the lesson to understand how social discourse gives rise to mental functioning.

Using my video recording device, placed unobtrusively in the front, I recorded and collected data during every class I taught. The recording was done on my iphone in the front of the classroom where the four desks the students sat around were in full view. Jim moved his work to another table so that I could use the table in the front and direct the students' attention to the white board and the screen, where they would also be facing the recording device. Each class was 80 minutes long and each unit consisted of 25-28 classes. I had a total of about 72 hours of video recorded data by the end of my teaching, which I found quite powerful in its capacity to provide illustrative evidence of how interactions were manifested in a teacher's situated practice in a classroom while the learners demonstrated growth in forms and functions when talking and negotiating the different questions at hand. This was a complex relationship with many factors in a learning situation that I could not have captured using any other design to be able to reflectively interpret the learners' and my perspectives and transformations. I saw many benefits in using a recording device as echoed by Morton (2018):

> Rather than simply providing teachers with language examples to emulate, it would be more beneficial to use a critical reflective approach (Mann and Walsh 2017) in which CLIL teachers themselves carry out analyses of examples of their own and other teachers' classroom language use (if possible, video-recorded), and comment on their appropriateness for meeting content-learning goals.

Some of the recorded hours were not useful for analysis, such as discussion among learners in pairs where they spoke quietly, or when I approached a group and kneeled by their table to clarify their questions with my back to the camera. As many of my lessons and activities were hands-on inquiry within pairs or groups with a significant portion of class time devoted to students' oral presentations and a smaller percentage devoted to whole-class discussion or lecture style teaching, my data was narrowed to about ten hours of video recordings where interactive classroom discourse was audible and could be analyzed.

3.5.3 Data Collection Process

The definition of a longitudinal study as Paltridge and Phakiti describe it entails researchers "gather[ing] the same aspect of information from the same participant(s) over a period of time. This allows researchers to observe change or stability in behaviour, learning, and/or other cognitive/social development" (p. 12). I describe my study as longitudinal in that the same participants and the same aspects of learning (language competency, conceptual understanding, negotiation and reasoning skills, teacher language awareness and the rhythm of the classroom discourse) were under scrutiny. Furthermore, I took advantage of "triangulation" in inviting multiple sources and forms of data to inform my research. Data triangulation refers to "the strategy of collecting information from different or multiple sources to help gain a deeper understanding of a particular matter" (Paltridge & Phakiti, 2015, p.15). Denzin originally conceived triangulation as a strategy of validation as "the combination of different data sources that are examined at different times, places, and persons" (Denzin & Lincoln, 2018, p.799). To me, triangulation does not mean fact checking or striving for conformity from multiple sources. In my view, triangulation increases the level of knowledge and widens the researcher’s horizon in a similar manner that one’s place in nature can be revealed to self through multiple senses; touch, temperature, light, smell and sound. Following this naturalistic principle, I have collected many sources of data, such as students’ journals, video-recordings of all lessons including the debates, lesson plans, lab experiments, group projects, as well as students’ written assignments and video-recording of their oral presentations.

I have chosen to use only the video recordings of class time where audible and intelligible verbal interactions are present between the students and me as well as among the students in pairs or groups. I have also chosen to use journal entries from two of the pupils who had good attendance and took advantage of the opportunity to reflect in their journals during the first few minutes of each class. Journals were written every class for the purpose of reflecting on a previous lesson, making a connection or responding to a question posed. The students were free to express themselves in their journals in the form of a drawing, point-form or paragraphs. They were also free to use the time to ask me any questions they may have. The journal entries I have selected, have the potential to disclose to me the learners’ conceptual understanding of the topics of discussion as well as their challenges and struggles.

3.6 Broader Questions around Research Design

In this section, I will briefly discuss ethics, validity, reflexivity, legitimacy of one’s study, and reliability in qualitative research in order to describe what is valid research to me and how my research paradigm reflects each of these properties. Generally defined here, the descriptions provided below have been made use of in some discussion of teacher research in the field of applied linguistics.

Ethics asks the questions of what is the purpose of the research and whose interests are advanced. It also asks which parties are involved or affected by this research. For a researcher, to judge what is ethical or moral depends on her own experiences, values and political positions, and also on her professional culture: the norms that appear acceptable in the professional setting (Mason, 2018). In education, a fundamental ethical question is how the design of the research enables educational improvement, more effective outcomes for students and empowerment of teachers. Thus, Paltridge and Phakiti (2015, pp. 98-99) suggest asking the following three questions when thinking about the ethical issues of a research study: 1) whose permission or consent is needed for the research, 2) who will be affected by the research, and 3) who should be told about the research when it is completed? To respond to the first question, I needed to gain permission from the West Vancouver school district and from SFU's ethics committee to be able to have access to the adapted science classroom. Following that, parental consent forms were sent home and returned with signatures indicating parent permission before I could commence my research. In response to the second question, the findings of my study will impact the students whose course of educational lives are decided by practitioners who often do not have any training in teaching English language enrichment programs or those who are experts in teaching language skills but not in a disciplinary subject area. The findings will also impact teachers who are placed in teaching positions in adapted science classrooms unaware of their demands and challenges. Lastly, the findings will have broader implications for teacher training institutions which seem to have drawn a blind eye to issues of the quality of classroom lives for both ELLs in senior level content courses and their teachers.

Validity or trustworthiness in qualitative research is closely linked with the subjectivity of research discussed earlier in the chapter. To operationalize the concept of validity, one needs to ensure that he/she is observing, identifying or evaluating what has been intended. In classroom research, transparency as well as submission to data "in a way that the unexpected is allowed to emerge" (Paltridge & Phakiti, 2015, p. 52) are key principles of validity. In order to maintain validity in my research, I will need to be concerned with the adequacy of my findings. In other words, the emerging themes need to address directly the purpose of the questions. How and in what manner are the learners in adapted science class benefiting from classroom discourse? Is student learning outcome an accurate indication of the success of the lessons? Could my observations of a particularly engaging classroom discourse in some of the sessions offer a more accurate indication of the success of the lessons? How about considering students' length and depth of writing in their journals as an indication of enhanced learning? In short, I will need to be open-minded to all emerging themes in order to maintain validity.

One's own role or history in the project and her anticipated influences over the findings will need to be taken into account. In qualitative studies, reflexivity involves making the research process a focus of inquiry, in which the collaborators (in this case, myself and my students) are involved in knowledge production. Reflexive practices allow for revising questions and data for emergent findings at multiple parts of the data analysis process (Blaxter, Hughes, and Tight, 2006; Mackey & Gass, 2005). To me, this is analogous with an athlete training for a sport where the sheer process of training has caused changes to the athlete's body. The research process has similarly caused changes to my views of self, of others and of teaching in a way that at multiple visits to the data, I may find my role playing a different part: did I give empathy in the role of a teacher, a mother, a person of colour, or an ex-ELL student experiencing a science classroom in Canada? Or was my role later changed to a course facilitator who was keen on learning the students' passions, interests and strengths to engage them in dialogic discourses? Would it be possible that I also played the role of a researcher, concerned with the outcomes of the research and driving a hidden agenda to reach findings in accordance with pre-set goals? To be reflexive means to be aware and objective in revealing all possible roles played in the course of my teaching and later data analysis.

Reliability**,** or dependability in qualitative research, allows the research community to understand any changing conditions that are associated with the participants, the setting under examination, and any research modifications researchers make as the study progresses (Paltridge & Phakiti, 2015). To showcase reliability, legitimacy of the study will also need to be accounted for. Paltridge and Phakiti define legitimacy as "the extent to which we can trust the research findings; that is, what the researchers claim as knowledge and understanding of a research problem" (p.20). To attain reliability and legitimacy in my research, I aim to offer a detailed, clear and transparent report of the process of data analysis, all the avenues of arriving at conclusions and any changes that may have occurred in the process.

3.7 Data Analysis Tools

3.7.1 Applications of the CA Framework in Adapted Classrooms

First, I will discuss the nuances of an adapted classroom in terms of the long-term goals most programs hope to achieve. In the context of minority students learning curricular content in schools via a language medium foreign to them, criticality has recently become a central issue (Darvin, Lo, & Lin, 2020; Flores & Rosa, 2015; Sato et al., 2017). To be critical means to question the status quo and in order to do that science teachers need to start with probing students' prior knowledge; that is, they need to learn students' everyday science views and their definitions of science because students' prior knowledge influences subsequent learning of scientific concepts. In other words, science teachers in adapted classrooms need to involve students in talk, whether it is via student debate about science-related social issues, inquiry-based science lessons for collaborative activities, or argumentation as an accepted practice of science. However, the routine of teacher presentation, genres of certain registers and text types also need to be given equal attention.

In this kind of tensioned dichotomy between dialogic and authoritative approaches, in a CBI context, the CA framework can hold promise for effective analysis of the rhythm of the adapted classroom established by the shifts among a diverse range of teaching interactions. Both CBI and CA frameworks advocate for the dual purpose of familiarizing the learners with the dominant discourses in science and the established disciplinary norms while teaching them the registers of exploring, questioning, considering others' viewpoints and being critical while making meaning in the process of language and content learning.

Second, in considering the application of CA framework to an adapted science classroom, I will pose some questions in understanding the empirical data in the study. I will return to these questions in the conclusion section of the dissertation to evaluate the usefulness of the framework in its application to teaching in adapted settings. Questions to ponder upon when analyzing my data are as follows:

What could be potential differences in the way I interact with my students in talking about the science subject matter in comparison with other teachers in mainstream science classes?

- How can I move away from the existing, presentational practice of science teaching to invite students' voices in an atmosphere of developing language skills and self-esteem?
- How can I adopt a teaching practice to create room for different points of view when cultural and educational variations give rise to a wide spectrum of everyday science experiences?

- Where are the channels of communication in my adapted science class broken and are they due to language barriers or gaps in science knowledge?
- How do students express their ideas if language is lacking/insufficient?
- Can a dynamic and dialogic approach be feasible considering language leaners' lower rates of class participation and response?
- What knowledge might teachers of adapted science need to invite student participation?
- What knowledge might teachers of adapted science need to navigate the shifts between differentiated discourses to benefit both learners' conceptual and language learning?

I will take advantage of this analytical framework and apply its tenets to the analysis of classroom discourse in an adapted setting where attention to non-disciplinary language is just as crucial as attention to disciplinary and technical language while the scientific concepts are simultaneously shaped and reshaped in relation to the teacher's expertise and level of content knowledge.

3.7.2 Applications of Language Pedagogies in the Data Analysis

In order to zoom in on the discursive shifts from dialogic discourse (where multiple perspectives are considered) to authoritative discourse (where only one, often the school science view, is considered), the adapted setting poses an added layer of language accommodation which can assist in understanding these shifts. The 5R Model allows for identification of places and times where the teacher naturally accommodates students' language needs on a lexical level by utilizing one or more of the five moves. As discussed in the previous chapter, the 5R's are broken into the following language accommodation moves: *replace, reveal, repeat, reposition and reload*. They form the backbone of vocabulary instruction in scaffolded science inquiry to provide a structure for the parallel development of scientific and non-scientific vocabulary. In utilizing the 5R model, I will examine the shift between the two communicative approaches of dialogic and authoritative to infer whether vocabulary instruction hindered, delayed, advanced, or facilitated the natural progression of how science concepts opened up, developed, and were internalized by the learners. In other words, the 5R moves provide a new lens in understanding the shifts in language and content teaching where classroom interaction can be analyzed.

Beyond lexical scaffolding, interventions to teach the system of choices and patterns of sequencing, ranging from the levels of discourses to lexico-grammar to phonics (a top-down approach) or starting with English phonics and progressing to words, word groups, and to eventually teach genres of text (a bottom-up approach) need to be understood and analyzed in an adapted setting. While genre-based pedagogies lend a practical hand to teach these linguistic demands at different levels, the Genre Egg framework offers an integrated approach to linking the discipline-specific cognitive learning objectives with the linguistic representations they are afforded through classroom discourses. This framework allowed me to analyze teaching of language in my data in order to answer the following questions: How much attention is paid to language instruction within my classroom interactions? Is the attention predominantly reserved to lexical scaffolding? Does language instruction impede or disrupt the content learning goals? How can CBI teachers increase teaching opportunities to scaffolding for not only vocabulary but all layers of the Genre Egg and all verbal actions of the CDFs (as described in the literature review chapter)? I will apply both of the pedagogical approaches mentioned here to analyze my data in the next chapter. Where language instruction falls short of addressing the many layers of the disciplinary language in my class, I will discuss how a CBI teacher could use the full potential of the two pedagogical strategies. In order to use my findings to make implications for teacher education, I will demonstrate in the analysis how both the Genre Egg and the CDFs could offer explicit and practical strategies to content and language teachers. I will use the Genre Egg in the analysis of the transcripts of classroom talk and the CDFs in the analysis of the students' written journals. Although CDFs are constructed for the purpose of scaffolding cognitive discourse functions in interactive classroom talk, they do lend themselves to supporting students' language in writing. The CDFs are useful in drawing the students' attention to ways they can match their purposes with the instrumental lexico-grammar. I will exhibit this practice in section 4.4 where students' journal-writing is analyzed.

The analysis of the language accommodation in the adapted classroom can allow for an examination of the interplay between content and language teaching and learning. Thus, in terms of my research questions, I am asking whether attending to the students' language needs inhibited the shifts between dialogic and authoritative approaches from resembling the discourse of a science classroom as described in Mortimer & Scott (2003) and Scott et al. (2006)? Or, on the other hand, did the added layer of language teaching provide opportunities for alternative modes of teaching and learning and effective meaning-making in both content and language? The common sense, yet surface, conclusion would allude to a disruption in content learning when language features need to be dissected and taught. I aim to use my classroom data where interactive discourses reveal meaning making and unpacking of language features and their purposes simultaneously and organically to show that the overlap of language and content teaching complement and fortify learning gains. This finding will address the question of how language accommodation moves interrupt or facilitate the rhythm of dialogic and authoritative interactional discourses,

3.7.3 Applications of the TLA Construct as an Analytical Tool

To use the construct of TLA as an analytical tool, I will draw from Andrews and Lin (2017) who have synthesized tangible components that I can identify in my teaching to measure high versus low levels of TLA. These components are written in the language of teacher ability or pedagogical competence materialized in successfully facilitating a lesson, transferring knowledge, defining gaps, and assessing needs. The synthesizing components are divided into three categories of what TLA looks like during 1) lesson preparation, 2) lesson facilitation, and 3) Impromptu. I first introduced these components in the literature review chapter in section 2.5.4 in a list and here I have summarized them into the format of a table for visual organization and for ease of referencing.

Table 1 Teaching Components in Connection with TLA

Lesson preparation	Lesson facilitation	Impromptu
- analyze language from the learner perspective - identify key features - highlight those features appropriately in examples - specify appropriate learning objectives - select material and tasks that suit the learners - select material and tasks that serve objectives	- provide appropriate language-related mediation/scaffolding - help learners notice key features in language - produce spontaneous examples and clarifications - monitor the language produced by students - limit potential sources of learner confusion	- alertness and quick thinking ease of access to the subject-matter knowledge - good level of communicative ability - constant awareness of the learners

(Andrews & Lin, 2017, p. 61)

Although the examples from Andrews and Lin (2017) do not produce an exhaustive list, I will highlight them in my data where appropriate to analyze and measure my level of TLA. In the episodes I have chosen to transcribe and examine, there may also be evidence of teaching strategies and awareness not listed in Table 1 which I will discuss. In narrating the episodes, I will use TLA as a lens to add yet another layer to analyzing the shift between dialogic and authoritative discourse, this time in terms of teacher awareness. The outcome has the potential to shed light on factors contributing to different patterns of discourse in addition to those suggested by Mortimer and Scott (2003), such as purpose, content and approach.

3.7.4 Justifying the Amalgam of Analytical Tools in My Research

The goal behind narrating a selection of episodes in the data analysis chapter is to paint a clear picture of the classroom talk, successes and failures of the interactions in my adapted science classroom and of the rhythm shifting between authoritative and dialogic discourses based on teaching purposes, content, disruptions due to language instruction, and teacher content and pedagogical knowledge. Ultimately, the goal is to understand how I supported the students to talk their way to an understanding of the scientific point of view; and on the grander scheme, to understand/ruminate over potential differences in the way I interacted with my students in talking about the subject matter in comparison with teachers in mainstream science classes.

The communicative approach framework (Mortimer & Scott, 2003) shapes the analysis of my research where the rhythm of the science classroom interaction is analyzed to better understand “teacher talk”; the tension between teaching strictly the school science view and teaching/scaffolding students’ everyday views of science. This tension can then be juxtaposed against what success looks like in the classroom in terms of student participation, learning outcomes, and the overall development of the scientific story. In order to ensure that Mortimer and Scott’s Framework was applicable to the analysis of classroom interactions in an adapted setting, I added a language instruction lens to my analysis introduced earlier. The 5R Model, designed by Weinburgh and Silva in 2010 was useful in its simplicity, intuitive nature and rigour as a teaching tool to assist me in shedding light on the diverse range of instructions and their impact on classroom interactions in an adapted setting in the presence of language barriers. To attend to language features beyond vocabulary, such as patterns of organization of text for specific functions, registers and genres in academic language need to be explicitly taught, rehearsed and eventually produced. The Genre Egg framework designed by Lin (2016) and the CDFs constructed by Dalton-Puffer (2013; 2016) were useful to me in answering the question of how to teach academic language so that content and language objectives are materialized in the same lesson. The application of the language accommodation 5R model, Genre Egg framework, and CDFs construct as data analysis tools sheds light on the promise of true integration between language and content teaching.

In this marriage between the CA framework and the language instructional tools, I am able to illustrate the nuances of the classroom talk and the rhythm of the discourse in my teaching and compare them with stories told by Mortimer and Scott (2003) and Scott et al. (2006). Lastly, I made use of teacher language awareness (TLA) as a construct in examining what kinds of teacher knowledge may impact the rhythm of the classroom discourse. This is a construct which bridges the gap between teachers' knowledge about language and knowledge to use language for pedagogical practices and to enact the curriculum (Andrews & Svalberg, 2017). Under the umbrella of TLA, language proficiency, subject matter cognition and beliefs, learner knowledge and pedagogical language knowledge come together (He & Lin, 2018). In analyzing my data, I will evaluate TLA depending on the components which Andrews and Lin (2017) have delineated as indicators of teacher ability or teacher pedagogical competence. I have explained these variables in detail in the literature review and argue that TLA becomes a useful analytical construct categorizing and interpreting my language awareness in terms of preparation and delivery of lessons. I can use TLA to make sense of the disparities which may reveal themselves in the communicative approaches when comparing classroom discourses during the course of the unit of genetics with the unit of earth science.

What knowledge and/or skills did I need to be able to design and deliver lessons to respond to the needs of my students in the adapted science classroom? How could I purposefully enact opportunities for language and literacy development in and through teaching science? What is the nature of the knowledge about language that I needed in order to enhance my pedagogical practice in the adapted classroom? Lastly, what knowledge base did I need to feel confident as a teacher of language and science in a high school setting? These are the questions I asked myself when watching my video recorded data and examined the way my lessons, materials, activities and verbal instructions opened up and/or closed the spaces available for teaching and learning. In analyzing my data, I needed to delve into the nature of the knowledge at the intersection of language and content.

The CA framework is an analytical framework, 5R Model - an instructional strategy, the Genre Egg - a genre and register-based pedagogy, the CDFs - a transdisciplinary construct and pedagogy, and TLA - a construct of knowledge and I find all of them to be useful tools in analyzing my data through tracking the development of science concepts while understanding the dimensions of instructional discourse of teaching “everyday” and “technical” language features. The purpose of utilizing the 5R model is to add a layer to the analysis of my data that pertains solely to lexico-grammatical instruction while the Genre Egg and the CDFs shed light on the organization of text-in-context mobilizing a social goal. The purpose of making use of the TLA as a construct to consider is in data analysis to compare the rhythm of the classroom discourse when TLA was (retrospectively interpreted to be) high and when it was low. In particular, I want to illustrate the connections between the teacher’s degree of TLA and the teacher’s readiness to enact language instruction using these analytical means. In the summary tables that follow the data analysis of each episode in the next chapter, there will be two rows added to the CA framework which will appear as “language accommodation and TLA”. To reiterate, in my data analysis, I will make use of the instructional tools specified above, and the TLA construct to modify the CA framework and make use of it in an adapted setting teaching science.

Furthermore, classroom discourse analysis makes use of Lemke’s (2004) point that the language of science is unique- a hybrid of natural language, visual/graphic representations, mathematical expressions, and specialized operations. In this sense, the use of drawings, graphs, symbols and graphic organizers in my teaching can be understood and utilized in my analysis of classroom discourse as well. Lastly, the model reiterates Gee’s assertions (2004) in the sense that communicating scientific meaning is also a reflection of the situated, socioculturally defined context- the textbook, the assignments, the classroom, the interactions, the greater educational institutions and the society. Therefore, the diverse range of teaching interactions in science classrooms and the different forms of discourse are indicative of the long-term goals the teacher hopes to achieve and model to the students to further their social engagement, agency and criticality. In my data analysis chapter, I will show how I have taken advantage of this lens in analyzing my classroom talk with my students when supporting them in internalizing the scientific story. Questions of where and how the learners displayed growth in “argumentative competency” (Kuhn, 1993) for the eventual goal of acquiring “scientific citizenship” (Gibbs, 2015) will be discussed. I will keep this discussion grounded in the context of pedagogical decisions and strategies which have the potential to manifest full and equitable opportunities in knowledge-building and competency-development to ELLs - to initially participate in the classroom science community and eventually in the global science communities.

3.8 Conclusions

Methodologically speaking my study represents teacher research in an exploratory approach to examine teaching and learning from the inside. It is non-experimental in a sense that the natural classroom activities, interactions, and pedagogy are used to shed light and give insight to finding knowledge without an agenda to generalize. The constructivism of Guba and Lincoln (1989) claims that what is nature’s unfolding truth reside in community consensus. What the participatory paradigm adds to this is the view that any conceptual understanding is itself set within a wider and deeper experiential context (Heron, 1996). In my approach, *classroom research* fosters participatory spaces within experiential context for the co-construction of knowledge between the teacher-researcher and the participants. According to Cochran-Smith and Lytle (1999), this type of research design constructs and reconstructs curriculum in order to bring about awareness to create equal access to opportunities and more equitable social relations. This notion resonates with my views that school curricula are means to create equitable social relations. Also, according to Cummins and Davison (2007), “the embedding of language teaching in a matrix of societal and global power relations plays itself out within classrooms in the concrete interactions between teachers and students” (p. 971). Similarly, I aim to use data emerging from classroom interactions to highlight greater topics of 1) classroom discourse, 2) teacher language awareness, and 3) effective pedagogies to promote greater learning.

In the words of Tsui (2007), “Teachers’ professional growth is situated and personal. It is important to understand the situated possibilities” (p. 1077). I believe that the chosen methods of data collection and analysis for my research will allow for the examination of the situated possibilities in my study and in my professional growth. In the dual role of teacher-researcher, I am able to hold on to teacher perspectives in research. Many situated possibilities are present in the perspectives and in the different ways of knowing that permeate epistemologies. I also hold on to the perspectives of an English language learner in mainstream science during adolescence, a science teacher of senior level high school, and a CBI teacher searching for solutions to improve learning conditions for my students. Thus, I aim to analyze my data to uncover and understand the areas of integration between learning outcomes and competency development (in cognitive and social domains) for my students within teacher-student discursive interactions. This overlap between knowledge-gaining and competency-building is an on-going thread beginning in the literature review chapter, examining issues of empowerment in CBI and CLIL studies, continuing throughout the data analysis where overlap is found, and picked up again in the final sections of the Discussion under "Discourse and the Development of Social Competencies".

Chapter 4. Data Analysis

4.1 Introduction

In this chapter of my dissertation, I will provide transcripts of communicative interactions with my students in the adapted science 10 classroom. The transcripts portray student-teacher interactions interlaced with student-student interactions in negotiating points of view and making meaning. I will also present a selected number of two of the students' journal entries where I can analyze student learning gains in conceptual content and writing skills. As outlined in the earlier chapters, the aim of the analysis is to explore the following broad *inquiry*: how might an inquiry-driven pedagogy unfold in a CBI science class and what can we learn from this process in relation to 1) classroom discourse, 2) English language learners' educational outcomes in terms of academic literacy, and 3) teacher language awareness? Based on the *research inquiry* with the goal to generate data, I composed the following *research questions*:

1. How do classroom interactional discourses in one adapted science classroom influence learning gains and knowledge-based reasoning skills?

2. How does TLA enacting language accommodation strategies impact the rhythm of classroom discourse and students' learning gains?

3. How can a CBI teacher raise the students' awareness of disciplinary language features and conceptual content features, and how does this help the learners develop criticality, confidence and a positive science learner identity?

4. What are the challenges of a teacher-researcher's study in designing and delivering inquiry-driven lessons for English learners in high school adapted science?

I have organized the data analysis chapter in a format that gives sufficient attention to each of the research questions in interpreting the transcripts. I will return to the questions in the discussion chapter to assess how effectively my data supported my findings in response to the questions. As a CBI teacher shifting between multiple roles (language knower, language user and language analyst), my researcher role, too, shifts between my teacher voice and analyst voice. In the data analysis, my analyst voice can be critical of my teacher role, it can be in consensus with it or it can be at conflict. I will try to differentiate between the teacher and the analyst who gained more knowledge from reading and researching after the teaching was done.

4.2 Teaching in the Unit of Genetics

Genetics is very complex even though, generally, students don't expect biology to be cognitively challenging as it is all around them. Students have pre-conceived and common-sense ideas about biology which can create barriers to understanding the academic viewpoint when applying what they know to build deeper, more complex connections (Oliveira & Weinburgh, 2017; Wu et al., 2018). While lesson planning for this unit, I needed to ensure that preconceptions and misconceptions were disclosed, discussed, and resolved early in the unit. In every class period, I began by introducing an inquiry question whose purpose was to elicit students' prior knowledge -either in whole class discussions or in their individual journal entries- to be able to contextualize their knowledge base within the developing scientific story. In each subsequent discussion, I added a new layer to the growing teaching and learning story while maintaining the connection between everyday knowledge and scientific knowledge, as well as content and language objectives.

The science curricula proposed by the BC Ministry of Education stated the following general inquiries for the unit of genetics in grade 10 science: 1) how DNA results in biodiversity, 2) how the structure of DNA is related to its function, and 3) how mutations and modifications occur. These inquiries were designed to expand and deepen students' understandings of genes, genetic variations and genetic modifications. In Table 2, I summarized the ministry's curriculum objectives for this unit to paint a complete picture of the goals I had to work towards in designing and delivering my lessons as well as the intentions behind the selection of the specific tasks, activities, and communicative approaches in each of the episodes from which I have chosen for my analysis. I have added my personal language targets for this unit (in bold) to the table below (Table 2) as there are currently no prescribed learning outcomes by the ministry addressing the needs of language learners in senior level science courses.

Table 2 Macro Scaffold of Genetics Unit

Unit Title	**Genetics**
Topic	DNA is the basis for the diversity of living things. (https://curriculum.gov.bc.ca/curriculum/science/10/)
BC Ministry Curriculum Guiding Questions	- How to determine whether characteristics are genetically inherited? - How to gather genetic data to study certain traits? - How to use genetic data to predict traits of offspring? - How can the probability of specific genetic traits be determined? - How can you make a game or activity to help other students learn about heredity? - How would you prepare for a debate on the pros and cons of genetically modified organisms?
Materials	Texts, lab equipment, games, power point, slide shows, and short films
Content target	- Students will study genes, chromosomes, gene expression and interactions of genes and the environment - Students will learn how genealogy, human genetics and the human genome project help better understand heredity - Students will compare mutations, adaptations and extinctions - Students investigate the effects of GMOs, gene therapy, and engineering on populations and ecosystems - Students will explore the implications of modern genetics
Language targets	**- Students will use present tense verbs to report on an experiment. They will use past tense verbs and adverbial time to report on chronological events in the procedures of their experiments.** **- Students will learn to paraphrase** **- Students will learn to use complex sentences, avoid Run-on's, and faulty coordination.** **- Students will use genres of description, definition-giving, classification, procedure, descriptive report, review and evaluation, reasoning/argumentation, debate, and interpretation on simple and subordinate levels.** **- Students will use scientific vocabulary: *genes, traits, environment, inherit, heredity, phenotypes (phenotypic), genotypes (genotypic), alleles, offspring, variations, diseases, evolve, pedigree, dominant, recessive, DNA, chromosomes, building blocks, nucleotides, nucleus, strand, code, sequence, base pairing, genome, organisms, ancestors, genealogy, mutations, variations, natural selection, breeding, genetic engineering, implications, and ethical considerations.***
Projects and assessments	Experiments & lab reports, essay writing, interview project, poster presentation, power point presentation, and debate
Interrelated mini units	1. Traits 2. Patterns of inheritance 3. DNA structure and function 4. Diversity of life (mutation, natural selection and modification) 5. Applied genetics and ethical considerations

In the next section, I will narrate a series of episodes, part of lessons that fulfilled the requirements of a few of the curriculum guiding questions. The episodes will include classroom interactions focused on the study of traits, genes, phenotypes, genotypes, DNA, chromosomes, alleles, genetic variation, and genetic modifications. The lessons involved a combination of journal writing, whole-class discussions, experiments, short animated movies, small group work, and a whole-class debate. The language objectives were based on developing skills to engage with the specialized genres of the science concepts, such as *defining, describing, classifying, explaining, reasoning, evaluating,* and *debating*. The content objectives were based on teaching and learning scientific concepts where observable and everyday phenomena such as "traits", "heredity" and "genetic variation" are intertwined with less-observable and technical entities such as "genes", "DNA" and "alleles". Thus, empirical causes (*our traits are influenced by our genes and our environment*) needed to pave the way for confirmation using science experiments (*the probability of genetic traits can be determined*), and to finally build scientific proof (*genetic variation can be utilized to create new traits in genetically modified organisms*). Table 3 summarizes the learning sequence that I aimed to achieve in this unit. The sequence demonstrates the episodes as linked chains of interaction.

Table 3 The Learning Sequence for the Unit of Genetics

Empirical causes	Our traits are influenced by our genes and our environment.
↓	↓
Scientific experiments	The probability of genetic traits can be determined.
↓	↓
Scientific proof	Genetic variation can be utilized to create new traits in GMO's

In the analysis of the data, the episodes are broken down based on teaching purposes, i.e., only a unifying teaching purpose is pursued in each episode from which the transcript is selected. In presenting the transcriptions, I added punctuation for the pauses and interrogative intonations. I coded my data based on the "triadic" (I-R-E) and "chain" (I-R-F-R-F) patterns of interaction (Mortimer & Scott, 2003, p. 40). On the transcripts, next to each utterance, I have labeled the questions that I posed as "initiation" (I); students' answers, comments or questions as "response" (R); and my acceptance or rejection of students' responses as "evaluation" (E). My feedback to the students or my comments to probe further and encourage others to participate without any formative assessment was coded as “feedback” (F).

Classroom interactions are analyzed using the CA framework with the following components: an analysis of the nature of the content, teaching purposes, patterns of interactions, and communicative discourses (Mortimer & Scott, 2003) plus the added layer of language accommodation based on the Genre Egg framework (Lin, 2016) and the 5R Instructional Model (Weinburgh & Silva, 2010), and the TLA construct proposed by Andrews and Lin (2017). The organization of the analysis of the episodes is as follows: 1) an introduction to the teaching activity of each episode, 2) the transcript of the episode, 3) the analysis of the purpose and the content objectives of the episode, 4) the analysis of the communicative approach, 5) the analysis of the language modifications and TLA, and 6) a summary list.

4.2.1 Episode 1: What Makes Us Who We Are?

In the two parts of episode 1 that I have chosen to narrate, I aimed to unpack for the students, within a writing activity, how to determine what “traits” are and whether traits or characteristics are genetically inherited. I used the following stepping stones to arrive at the overarching theme:

> First: Our traits make us who we are.
>
> Second: Our traits are shaped/influenced by our genes and our environment.
>
> Third: Our genetic traits are inherited from our parents in our DNA.
>
> Fourth: Variations in traits are due to crossing of two sets of parent DNA and due to adaptations to environmental factors.

The transcripts from the two parts of episode 1 will illustrate the first three stepping stones that were worked upon and episode 2 will illustrate an activity exploring the fourth point mentioned above. Episode 1 took place during the first teaching lesson in the unit of genetics.

<u>Episode 1- Part 1</u>

In the first part of this episode, the students were asked to respond in their journals to the question on the board: “What makes us who we are?” I was aware that the question was open-ended and could be answered using a variety of perspectives: biology, religion, culture, schooling, etc. I was also hopeful that a question around “who we are” would be highly stimulating to young adolescents, and that I would be able to engage them in the question and the follow-up whole-class discussion. The intent was to use this inquiry to probe students’ background knowledge and their knowledge of genetics. So, I asked the class to pretend that they are biologists when answering: “What makes us who we are?” Once the students had written down their thoughts, I asked them to write one or two key words from their responses on the white board. The following words shaped the students’ word map:

Table 4 Students’ Word Map

parents	biology	food
brain	cells	DNA
chromosomes	evolution	air
workout	earth	weather

Afterwards, I formulated a few sentences by borrowing words from the students’ word map (Table 4) to answer the question of “what makes us who we are”. I wrote my sample sentences on the white board (the words borrowed from the students’ word map are in bold as shown below):

> We are similar in some ways to our **parents**. So our **parents’ cells** or **biology** creates our **cells** or **biology**. But food, **weather** and **workou**t also make us who we are.

Then, I offered the students a second activity where I *revealed* new vocabulary pertaining to the topic at hand (see Table 5) and prompted the students to use the new terms to *replace* and re-write some of their own answers. I first modeled by using the sample sentences I had constructed. I did not frontload definitions of the new words and requested from the students to put away their electronic dictionaries. What follows next is the transcript of the interactions that took place in a whole class discussion when I asked the learners to consider my sample sentence and revise it together as a group.

Table 5 New Words Provided to the Students

traits	characteristics	genes
environment	offspring	DNA
chromosomes	inherited	unique

1 *Nikta: Try to incorporate maybe even just one or two of these words into your writing. Even if there is one in here that you know, take it and put it into your sentences. Let's go back to my sentence example which I wrote borrowing from your word map.*
The students' attention was directed to the sentences on the board:
We are similar in some ways to our **parents**. So our **parents' cells** or **biology** creates our **cells** or **biology**. But food, **weather** and **workout** also makes us who we are.
2 *Nikta: We are similar in some ways to our parents. What is a good substitute?* (I)
3 *Peyz: We are similar in some ways to our genes.* (R)
4 *Nikta: Do you guys agree? Is that a good substitute? Genes for parents?* (F)
[Nikta recognized she needed to point to the specific words for the students to consider.]
5 *Nikta: What if I underlined this?* (I)
[Nikta underlined "ways"]
6 *Peyz: Ways?*
7 *Nikta: Yes.*
8 *Peyz: traits?* (R)
9 *Nikta: Yeah!* (E)*. Does this help you understand the definition of "traits" a bit better?* (F)
We are similar in some traits to our parents. So what does "traits" mean? (I)
10 *Jerry: Special.* (R)
11 *Nikta: Special what?* (F)
12 *Jerry: Special looking.* (R)
13 *Nikta: Special looking! Great! Yeah, Jerry got it!* (E). *It's the background knowledge helping him. So what do you think he [Jerry] means?* (I)
14 *Peyz: We can't translate it.* (R) [Peyz means he knows the word in Farsi but not in English.]
15 *Nikta: Special looking… could the special way I look be a characteristic of mine?* (F)
Class nods. (R)
16 *Nikta: So do you think "traits" and "characteristics" are similar in meaning?* (I)
Class nods. (R)
17 *Nikta: Possibly!* (F)
18 *Nikta: May, I know you have this in your paragraph. If I underlined this word, what would you use as a substitute?* (I)
[Nikta moved to underline "cells or biology".]
19 *May: DNA.* (R)
20 *Nikta: Do you agree with May?*
Class nods. (R)

21 *Nikta: She thinks it'll sound more scientific if we say our parents' DNA makes us.* (E)
22 *Nikta: Food, weather, workout...What do I mean here by workout?* (I)
23 *Class: Training.* (R)
24 *Peyz: When you go to the gym.* (R)
25 *Nikta: So physical exercise?* (F)
26 *Class: Environment* (R)
27 *Nikta: Thank you!* (E)

Analysis of teaching purpose and content

The teaching purpose in this very first episode, aside from lexico-grammatical scaffolding, was to explore and learn about students' knowledge of genetics and environmental factors in relation to "traits" to eventually internalize the scientific story that "our traits make us who we are and that they are influenced by our genes and our environment"*.* In developing the scientific story that both genes and environment are essential in making us who we are, in the sample sentence, I purposely underlined "parents' cells or biology" and "food, weather and workout" to direct the learners' attention to these two types of essential elements (genes and the environment). This served both the content objective and the language objective of the episode, lexically engaging the learners to arrive at the elements responding to "what makes us who we are". To achieve both objectives during the same interactional exchange, I needed to form a bridge to connect the required lexico-grammatical items with the newly introduced concept of traits and what influences them. Therefore, I needed to 1) draw from the learners' past knowledge via scaffolding to build a word map, 2) use their word map to construct a sample sentence which unpacked the concept of "what makes us who we are" by classifying the essential causes (genetic and the environmental variables), and 3) bridge the tentative conceptual understanding to new science vocabulary by asking the students to revisit and *replace* the everyday lexical choices. In other words, three small and fragile yet connecting parts of a bridge were formed which collectively fortified each other and achieved the purpose of lexically and conceptually advancing the learners' meaning making process:

Part 1- Probing students' prior knowledge

Part 2- Accepting and validating students' vocabulary by formulating a sentence which used only the students' suggestions

Part 3- Asking the students to incorporate new scientific vocabulary in the sample sentence which offered an answer to the question at hand

To ensure that the resulting bridge was built on sound scientific knowledge, the sample sentence seemingly based on the students' suggestions, relied my content knowledge: genes and the environment are two empirical causes influencing and shaping our traits and thus defining who we are.

The aim of the episode was to also come up with a preliminary definition for "traits". In line 9, I made two requests to check for students' understanding of the word traits: "*Does this help you understand the definition of traits a bit better?"* and *"So what does traits mean?"* which prompted Jerry to say "special looking". Although I emphasized the need for a "definition", I did not properly scaffold the students or offered to the students a "definition". Whether Jerry's response was an attempt to define what traits are, perhaps equating "special looking" with how traits can be defined as "unique visible characteristics" - ("special" for unique and "looking" for visible); or whether Jerry was offering examples of physical traits, such as looks, height, hair colour, etc., is unclear. What is clear, is that the opportunity to introduce the lexico-grammatical pattern or the sentence pattern of *defining* was present while scaffolding and offering examples of traits were taking place in this episode. It would have been fruitful to orient the learners with the language function of *defining* so that when they encounter it in a science text, it signals to them that a definition is going to be given. Such a sentence pattern resembles the following equation (borrowed from Lin, 2016, p. 42): *technical term* + *relating verb* + *general class* + *phrase giving specific information*. In the case of the example in this episode, the students and I could have worked towards constructing the following sentence: *traits* + *are* + *characteristics or dispositions* + *that are influenced by our genes and our environment*. This sentence pattern would then be repeated and reviewed the next instance a definition was sought. In this manner, the learners could be oriented to the genre of *descriptive report* in science which involves *defining* and *describing*. A follow-up lesson - inspired by the Genre Egg (Lin, 2010; 2016) - on how the lexico-grammatical pattern of text conveys a certain academic register which will in turn inform genre and purpose of text would be very helpful in familiarizing the students with science sentence patterns and text structures.

In terms of content, although genetics is a complex field in science, the study of traits, heredity, and environmental factors are observable and traceable making the content familiar and common-sense to the students, as evident when comparing Tables 4 and 5. The comparison between the two tables reinforces that the students' initial thinking resonated closely with the social language of science in a topic firmly rooted in the everyday domain. In this instance, when content is everyday and relatable, I took advantage of the words the students offered to build a word map because they all connected well to the subject matter. It would have been useful to scaffold further and ask the students to classify their words in Table 4 into subgroups. For instance, students could group *parents, chromosomes, DNA* and *cells* into "genetic variables" and group *food, air, weather,* and *workout* into "environmental variables". In a similar vein, I could have clarified Jerry's response when he said "special looking" and ask if he was offering a definition for *traits* or if he would suggest to start a new category and call it "examples of traits" and if other students could contribute to this category by offering other examples, such as height, hair colour, skin colour, etc. In this sense, an opportunity to introduce another language function (*exemplifying*) would become available and I could teach the students how to *classify* and *exemplify* different broad classes or categories with specific examples from their own word map. As a result, classification of vocabulary related to the subject matter would become hands-on and student-centered.

When an inquiry, such as "What makes us who we are?" is everyday and experiential, the interactive discourse tends to motivate a high level of student participation, smaller leaps in the "learning demands" (Mortimer & Scott, 2003) and greater overall feelings of success evident in Peyz's substitution of "traits" for "ways", Jerry's translation of traits as "special looking", and students' substitution of "environment" for "food, weather and workout". Therefore, the nature of the content of the subject matter allowed for an easy passage from everyday to scientific views due to smaller learning barriers.

<u>Analysis of communicative approach and patterns of interaction</u>

In this part of episode 1, I offered the students a sample sentence to work with, based on their own brainstorming activity. This pedagogical move opened up the beginning of a dialogic discourse where the learners saw their responses as legitimate and their perspectives as valid. However, I borrowed and underlined from the students' word map only those terms which were in parallel with the scientific perspective developing an empirical description of the causes to establish the scientific story. Thus, in a dialogic discourse, I authoritatively formulated my sample sentences to include genes and environmental factors as responsible for traits in order to introduce the scientific view. The shift between dialogic and authoritative discourses was present in many instances in this first episode. In line 4, I posed to the students whether Peyz's substitution is a good choice of word, making the communication dialogic; however, in line 5, I quickly shifted to an authoritative discourse and underlined a new word, as Peyz's substitution was not aligned with the scientific perspective. In line 20, I chose May to volunteer her answer as her paraphrase using "DNA" was closer to the scientific view than the everyday terms of "cells and biology" offered by other students. Although the consideration of May's suggestion was dialogic, the act of calling upon May among many other students was authoritative on my behalf. Finally, in line 15, my question of "*could the special way I look be a characteristic of mine?"* although it rose from Jerry's background knowledge and seemed to invite students to arrive at their own conclusions dialogically, pushed forward the school science view that traits can determine physical characteristics. Overall, what seemingly presented itself as a set of interactive, dialogic exchanges in this episode, was authoritatively orchestrated. Whether such shifts in the communicative discourse benefit the learners and influence the learning outcomes positively will be a topic of discussion in the next chapter of the dissertation.

It cannot be ignored that the dialogic interaction to consider Jerry's point of view and allowing it to shape the process of meaning making for the other students had some benefits. For one, as Scott et al. (2006) state, "meaningful learning involves making *connections* between ways of thinking and talking" (p. 622 italics in the original text) and for Jerry the connection between his thinking and talking was evident. Second, the students saw that their peer's background knowledge was validated, built on and incorporated into the science language of the classroom. Third, the Mandarin-speaking students likely benefited from Jerry's translation of "special looking" as it is possible that it is a close translation for "visible traits" in Chinese Mandarin and therefore helpful in lexical advancement. However, asking clarification questions or, as suggested earlier, checking whether Jerry was offering "special looking" as an example of a category of traits would have unpacked the concept more effectively. In this regard, Jerry's suggestion could have supported students' understanding of "phenotypic" versus "genotypic" traits where phenotypes are visible traits and describe how we look. Although, equating "traits" with "special looking" demonstrated that the concept was not yet fully explored at this point, the consideration and validation of Jerry's point of view and returning to it later in future episodes could enhance students' empowerment and conceptual understanding. This is a relationship that I will expand on in the discussion of the findings: are there ways of communication in the classroom which promote learning outcomes while positively influencing critical thinking, agency and confidence building?

In terms of patterns of interaction, I started with a question: "*What makes us who we are?"* and the students' responses were followed by a request for elaboration in line 4: "*Do you all agree? Is that a good substitute*?" When the students offered their views, I brought them to the whole class for discussion in line 9: "*does it help you understand the meaning of traits a bit better*?" Here, it may seem that I was being negatively evaluative; however, the video recordings showed an affirmative body language and nodding of the head to demonstrate a request for elaboration or justification of Jerry's response. As the teacher, I did not evaluate or correct, but simply asked for further clarification and prompted others to position themselves in the discussion. Thus, the discourse patterns of interaction included more of the feedback chain (I-R-F-R-F) than the triadic (I-R-E) which again allowed the interaction to fall closer to the dialogic than the authoritative end of the framework. In this way, I used open chains of interaction, with few evaluative feedbacks, to support an interactive-dialogic communicative approach, with a clear purpose of exploring and probing students' views.

<u>Analysis of language accommodation and TLA</u>

The 5R model of language accommodations can be used here to show that I integrated into the first episode two moves: 1) *reveal*, providing the learners with the academic terms that did not exist in their everyday science language and 2) *replace,* allowing the learners to experience how words can assist in meaning-making of scientific ideas while honouring their non-scientific language. In instances where everyday terms were in their early stages of maturation, such as "training or going to the gym" to approximate "environmental factors", I probed further until the matching scientific term was found. I also posed clarification questions to the class in lines 9, 13, and 25 to reduce any language barriers.

In terms of TLA, the ongoing shift between dialogic and authoritative discourses in this first episode displayed high levels of awareness of the learners and ease of access to the subject-matter knowledge on my part where I could invite and weave students' responses into the talk of the lesson, while authoritatively advancing my agenda. First, I believe that an awareness of the learners' developing language abilities was exemplified where I showed that I was able to probe their prior knowledge in a way that their suggestions, ideas and viewpoints formed the skeleton of the sample sentence which was deconstructed and jointly reconstructed. I showed the ability to analyze the target language from the perspective of the learners when I underlined their everyday words to help the learners see their connections with technical words. Aside from selecting and underlining key content for the students to engage with, I also strengthened the bond between students' prior knowledge and the process of meaningful learning of new concepts. What is more, in this episode I chose to start with *revealing* and then *replacing* words in a sample sentence based on the students' word map to display that any learner's first attempt could be modified and improved with the help of more academic and expert terms. This demonstrated to the students that their initial attempts were used as a foundation for further content and language development, that I honoured their non-technical language for sound content and aimed to build upon it with scientific terms to develop both language and discipline specific content (Oliveira & Weinburgh, 2019). I speculate that the awareness of leaners and the awareness of their social and emotional needs in this first episode, assisted me to encourage students' construction of identity as capable learners of science which potentially promoted empowerment and greater learning outcomes as outlined in the literature review.

Second, I showed an ease of access to subject matter content. I raised the awareness of the key features of the content language, such as academic vocabulary, as well as what needed to be highlighted to establish the scientific story while validating students' input. Access to content knowledge was displayed in building the bridge to connect students' everyday words with technical words via the concept being unpacked. However, as "an analyst" who has gained more knowledge about TLA since the time that I played the role of "the teacher" in this research, I now see that most of the components of the construct of TLA which I displayed in this episode were limited to an awareness of lexical features, exhibited via the *reveal* and *replace* language moves. The many layers of the genre of descriptive reporting within the "Genre Egg" (Lin, 202) such as sentence patterns and academic functions were not explicitly taught. With the lens of "an analyst", I recognize that there needed to be a wider range of TLA, especially in orienting the learners with the language functions of *defining* (in the case of defining *traits*) and *classifying and exemplifying* (in the instance of *special looking*). Developing a deeper TLA at the time of my teaching and data collection could have facilitated a greater understanding of lexico-grammatical patterns and linguistic choices for the purpose of teaching the genre of descriptive writing to my students so that they could respond confidently to "what makes us who we are".

<u>Episode 1- Part 2</u>

In the second part of episode 1, the students returned to their writing by replacing their everyday words with the suggested scientific words. Then the class watched a short animated movie discussing the topic of "what makes us who we are." Again, the students revisited their writing to incorporate into their work any new ideas that they learned from the video; but this time, they did so in pairs. Near the end of the episode, two groups volunteered to share their writing with the class.

Many of the classroom interactions in the adapted setting during my data collection revolved around my engagements with the students' perspectives presented not verbally but in the written form. The demand of scientific language is multidimensional and I needed to rely on a variety of communication strategies to teach language and content to ELLs. For language learner students, writing out their thoughts offers opportunities to think, construct, edit, revise and to avoid the pronunciation of the new words if there is uncertainty in their minds about sounds and intonations. The challenges of oral comprehensibility can inhibit language learners from participating in class oral discussions, even those with rich backgrounds in content knowledge (Lee, 2009; Leki, 2001; Wu et al., 2018). Searching for lengthy verbal exchanges between myself and the students in my data to be able to draw comparisons with the classroom interactions from Mortimer and Scott (2003) and Scott et al. (2006), was not fruitful. However, viewing learners' written work as their form of participation, exchange of ideas and expressions of thought, helped me delve deeper into the teaching and learning communication approaches and the process of meaning-making in the adapted science. Thus, many communicative discourses in my teaching were not in the form of verbal interactions, eliciting responses, but in the form of an engagement with the learners' written responses. In these interactions, I read their work out loud, deconstructed and evaluated it while the students observed and at times got involved in the consideration (or rejection) of their written ideas. This second part of episode 1 is an example of this recurrent type of communicative approach where the students worked in pairs to articulate (in writing) their thoughts to the question: “what makes us who we are?”

1 *Jerry: Nutrition is important for human growth. I have different trait from others. (R)*
[Nikta wrote the group’s sentence on the white board.]
2 *Nikta: Do we have just one trait? (F)*
3 *Class: Many! (R)*
4 *Nikta: Ok so should we put an “s” here? (F)*
5 *Class: Yes. (R)*
6 *Nikta: I have different trait(s) from others. (F)*
7 *Nikta: If you have different traits, then what does that make you? Key word from the video? Do you remember? (I)*
8 *Class: unique! (R)*
9 *Nikta: Great! So this makes me unique. (F)*
[Nikta extended the group’s sentence on the board.]
10 *Nikta: Here Jerry’s group is talking about nutrition. That goes back to another key word. Something that’s not part of our genes. Nutrition is not in our genes. It’s part of our? (I)*
11 *Class: Environment. (R)*
12 *Nikta: Yes, environmental factors. Thank you, Jerry’s group! Great sentence! (E)*
13 *Nikta: Who else? Lisa and Yuki wrote a sentence that sums it all up. Can you please put it up on the board, Lisa? (I)*
[Lisa’s sentence on the white board: We inherit trains from our parents in our genes.] *(R)*
14 *Nikta: I’ll change the N to a T. Traits. But it does sound like “trains”, doesn’t it? (F)*
15 *But, I really appreciate how they have the words “traits” and “genes” connected through the meaning of inherit. We’ve seen this word before, “inherit”, yes? Is this word new to anyone? (I)*
[Most students nodded in agreement.] *(R)*
16 *Nikta: What if I said “when my grandfather died, my dad inherited some money”? (F)*
17 *Class: Oh yeah! OK! Yeah! (R)*
18 *Nikta: You get it! Same word in science. Same meaning. (F)*
19 *Nikta: Would you say it’s a noun or a verb? (I)*
20 *Rentaro: verb. (R)*

<u>Analysis of teaching purpose and content</u>

The teaching purpose in the second episode was to guide the students to work with science meaning, support the internalization of the scientific story, build confidence and to familiarize the students with new vocabulary in the language of school science. Exposing the learners to new language of science is a big part of teaching in the adapted setting and it can be accomplished very effectively when new science words are offered by the students themselves. The selection of the students’ written work as exemplary planted the seeds in building confidence in the students to view themselves as knowledgeable and as linguistically competent. Therefore, I selected work from groups which offered new words that had not been discussed, such as “unique” and “inherit”, for the class to consider.

I return to Scott et al.’s (2006) statement that: “meaningful learning involves making *connections* between ways of thinking and talking” (p. 622 italic in original). In Lisa and Yuki’s example, I took the pair’s written response to guide the class to focus on the conceptual meaning of “heredity” via the exploration of “genes”, “traits” and “inherit”. Lisa and Yuki’s sentence was perfectly succinct and an accurate articulation where the three new terms had been connected to bring forth the conceptual understanding of “heredity”. Lisa and Yuki did a great job utilizing their knowledge of the terms in displaying “mental functioning” (Mortimer & Scott, 2003). The internalization of the school science view was successful and the facilitation of science meaning was achieved. To further help the students grow in their understanding of genres of science text which is mainly descriptive reporting, as the analyst reviewing my own teaching, I see that I could have used the class examples to reveal to the learners the lexico-grammatical or sentence patterns of *defining* and *describing* language functions. For instance, I could have raised the students’ awareness of the following formula (Table 6) for *defining* (borrowed from Lin, 2016, p. 44):

Table 6 The Lexico-Grammatical Pattern Realizing the Function of *Defining*

Technical Terms	Relating Verb	General Class	Phrase Giving Information
Traits	are	characteristics	of organisms
Traits	are	features	that are unique to each organism
Traits	are	qualities	that are passed down from parents to offspring
Traits	are	features/qualities	that are influenced by our genes and our environment

Using a graphic organizer such as Table 6 would have benefited the learners dually: advance the conceptual meaning of “traits”, and teach a language function essential in science, such as *defining*. As Lin (2016, p.51) delineates, “[language] functions are simultaneously cognitive and linguistic/discursive” which is why an awareness of language in realizing functions via a structural pattern is extremely useful to ELLs. This type of a pedagogical extension in this episode, could have helped the students see existing patterns of organization in specific language functions, first, to recognize them in context and, second, to produce them when necessary.

In terms of content, when the language of science has borrowed from everyday social language, the learning barriers are reduced for learners (Mortimer & Scott, 2003). In line 15, where Lisa's group presented, I noticed a potential gap in language and asked if the word "inherit" was new to the class. When most students confirmed that the word was unfamiliar to them, I offered the class an example from the language of the social plane to convey the meaning of the word "inherit" (line 16). Once the students grasped the meaning of the word from, "my grandfather died and my dad inherited some money", then they applied their knowledge of the lexicon to make sense of the language of science in Lisa and Yuki's sentence: "we inherit traits from our parents in our genes". As the scientific content behind this lexical scaffolding is embedded in the everyday social language, I was able to make the direct juxtaposition of everyday and scientific views possible which in turn supported meaningful learning. Furthermore, Jerry's example (line 1) also facilitated transformation in content moving from here and now of everyday views "*nutrition is important to human growth*" to the generally applicable statements of science where content is gradually decontextualized in *categorizing* nutrition as an "environmental variable" (line 12) important for human growth.

As discussed in the literature review chapter, Lemke (1990) describes learning content in the science subject as a semiotic process where the scientific technical terms are used in construing the world and making sense of everyday experiences. In a similar vein, I see the learners in this episode, using the field-specific vocabulary to unpack and understand the concept of heredity starting from the classification of genetic versus environmental factors, understanding traits, and understanding inheritance. This endeavor became possible because the learners' original common-sense and everyday language resonated closely with the language of the scientific subject, which in turn allowed for the growth and approximation of ideas in the sense that the writing activity became a tool to unpack the concept of "heredity". In this activity, we worked together to formulate a sample sentence based on the learners' word map followed by the students working in pairs to construct their own sentences. A similar activity, called the *Teaching/Learning* Cycle (Martin & Matthiessen, 2014 in Lin, 2016) shows great benefits when text is deconstructed and reconstructed involving the students in the process. The joint construction (steps 1 and 2) and later independent construction (step 3) of the sample sentences are as follows:

Step 1: We are similar in some ways to our parents. So our parents' cells or biology create our cells or biology. But food, weather and workout also makes us who we are.

Step 2: We are similar in some traits to our parents. So our genes create our cells or biology. But the environment also makes us who we are.

Step 3: We inherit traits from our parents in our genes.

It is clear that each sentence was extended from the previous and in the process each had become more succinct. Such rich writing activity has the potential of advancing the learners onto paragraph writing and eventually essay writing.

<u>Analysis of communicative approach and patterns of interaction</u>

In the second part of episode 1, I considered the written work of two pairs of students to be discussed with the class due to the fact that they illustrated the students' points of view clearly and communicated the disciplinary knowledge accurately. I classify these interactions as dialogic for the consideration of plural accounts and validation of students' perspectives as examples of scientific views. In saying to the class, "*Here, Jerry's group is talking about nutrition*" and "*Lisa and Yuki's sentence sums it all up"*, I shifted the discourse to the dialogic dimension of the framework for the purpose of working with students' views to facilitate the internalization of the scientific story. Scott et al. (2006) state that "according to our definition, we are clear that in dialogic discourse the teacher recognizes and attempts to take into account a range of students', and others', ideas" (p. 610). In the adapted teaching environments, I see it necessary to add to Mortimer and Scott's communicative framework, the range of students' ideas in the written form that display expressions of knowledge where ideas and voices shape the talk of the lesson while the teacher considers others' perspectives with varying levels of interanimation.

Another point that this episode brings forth is that in the adapted settings, much attention needs to be paid to language instruction which includes the introduction of vocabulary items most preferably discovered and understood within an inquiry. However, when the teacher's questions about new words are met with silence, a gap is identified which often prompts an authoritative interaction where quickly and efficiently the teacher delivers the missing information, as observed here with the word "inherit" in line 16. This type of intervention where the teacher shifts her approach from dialogic to authoritative for the purpose of filling in a gap in language is common and efficient (Weinburgh et al., 2014; de Oliveira, Obenchain, Kenney, & Oliveira, 2019). To invest in lengthy dialogic exchanges for the students to guess at the missing definition while the teacher considers or rejects their ideas, would be fruitful; but in actuality it would consume a large percentage of class time. Thus, with no hesitation or shame, the filling of the gap for the new word, "inherit", adopted a lecture-style, authoritative approach.

The overall pattern of interaction in the second episode follows the I-R-F-R-F chain (as labeled on the transcript) typical of dialogic discourse for prompting intellectual engagement. In places where I used my authority to move towards the final acceptable explanation (developing an empirical explanation, "*traits are inherited from our parents in our genes*" or discussing the meaning of "inherit"), I either paraphrased students' words and elaborated or drew their attention to the differences between their initial work and the generalized, decontextualized explanation. Thus, the authoritative evaluations were confirmatory exchanges, setting up an I-R-F pattern.

<u>Analysis of language accommodation and TLA</u>

The language interventions that I utilized in this episode were checking for students' understanding, noticing a gap, filling in the gap, paraphrasing and extending the initial sentences. In terms of language modification, attention was paid to word form, whether "inherit" is a noun or a verb and adding an "s" to "traits" in line 4 which qualifies as *reposition* in the 5R Model. Furthermore, the leaners revisited some terms introduced to them in the previous episode which allowed for the move *repeat* to take place. Lastly, the students' written work was in response to my instructions to move beyond definitions and see the relationship between ideas (as evident in Lisa and Yuki's work where the disciplinary word, "trait", was coherently connected in expressing a single meaning, "inheritance"). This is the *reload* mode in the 5R model which I utilized to help the students develop an early attempt at classifying the essential causes: *both genes and the environment determine our traits.*

My teacher language awareness was mainly on a lexical level, which I realize now as "an analyst" who knows more about TLA than the teacher role I performed at the time. I instigated dialogic interactions where I tied students' ideas into building the scientific story: "*If you have different traits then what does that make you?"* (response: unique), and "*Nutrition is not in our genes. It's part of our*?" (response: environment). In these examples, I display appropriate language-related mediation and scaffolding which according to Andrews and Lin (2017) is realized due to the presence of TLA on the level of vocabulary scaffolding. The ability to apply my content knowledge in this episode, allowed me to progressively recontextualize the talk of the lesson while identifying the essential causes for heredity, a sign of "ease of access to subject matter knowledge-base" (Andrews & Lin, 2017, p.61).

I not only encouraged the group's use of technical terms but I also modeled for them how to extend their writing further to become fluent in the speech genre of school science where language underpins science learning; another sign to illustrate that I was monitoring students' language production. To advance further in raising students' awareness of not only lexical items of the subject matter but also academic functions, I could have scaffold the writing activity further. A useful activity in this teaching episode, as I introduced earlier, would have been the *Teaching/Learning Cycle* (Martin & Matthiessen, 2014 in Lin, 2016). This type of pedagogical work requires great language awareness to dig deeper and to orient the learners not only with the discipline-specific vocabulary but also with the sentence patterns of *defining, classifying, contrasting*, *describing* and other language functions in science.

Another example of TLA was evident in offering the learners a clarification for "inherit" embedded in the language of everyday. This move illustrated my ability to produce spontaneous examples and appropriately-formulated clarifications. An additional example of my TLA, again mainly at the lexical level, was found in praising Lisa and Yuki for demonstrating a good understanding for the meaning of inherit: "*I really appreciate how they have the words traits and genes connected through the meaning of inherit".* Here, I display my ability to monitor the language produced by the students- a sign of awareness of the learner; however, also increasing my awareness of genres of science text and helping the students independently construct their own definitions of "inherit" would have been a helpful activity. According to the Genre Egg framework (Lin, 2010; 2016) scaffolding can take place in an integrated, top-down and bottom-up approach. In my example, I could have applied a top-down approach (using Yuki and Lisa's sentence and asking the learners to infer or deduce what kind of language function it conveys); also, I could have applied a bottom-up approach (using "inherit" to ask the students to devise a definition following the sentence pattern of *defining*). As a result, gradually, the students would become capable of both learning to read and reading to learn. Below is the summary of the elements of the CA framework, the 5R model and the TLA components reflected in my teaching/instructional approach for the two parts of episode 1.

Episode 1 Summary List: What makes us who we are?

Teaching Purpose	- Lexico-grammatical Scaffolding - Exploring and probing students' everyday ideas about factors which determine our traits - Guiding the students to work with science meaning and supporting internalization
Content	- Describing everyday ideas and looking for connections to scientific explanations - Building from everyday language to technical science language
Approach	- Interactive/dialogic
Patterns of interaction	- I-R-F chains
Language accommodation	- *Reveal, Repeat, Replace, Reposition* - Scaffolding on a lexical level
TLA	- Probed prior knowledge - Deconstructed and jointly reconstructed at sentence level - Analyzed the target language from the perspective of the learners - Strengthened the bond between students' prior knowledge and new concepts

4.2.2 Episode 2: Alien Babies

Episode 2 was in response to one of the Ministry's guiding questions in this unit: "How can you make a game or an activity to help students learn about heredity?" I chose an activity for the students to create alien babies by randomly selecting two alien parents and crossing them (see Figure 1). The purpose was to help determine the probability of offspring being born with certain genetic traits using two-letter codes, called *alleles*.

Alleles were used to represent the traits and their variations, in this case: body colour, hair colour, antenna, etc. The students were asked to cut out the parental alleles printed on different colour paper, toss them into a beaker and randomly draw from the beaker. A table (see Figure 2) was used to help the learners arrive at the disciplinary terms of “genotypes” and “phenotypes” by respectively organizing the results into “what the DNA says” and “what we see”. Mortimer and Scott (2003, p. 105) state that, “[s]tudents comparing their views with the scientific one helps them make sense of the scientific story” which was precisely the aim of this episode. Here, I return to the learning sequence (Table 3) progressing from *the empirical descriptions* to *confirmation using science experiments*, as discussed in the initial part of this chapter. The content objective of this episode was to use confirmation via an experiment to prove that the probability of genetic traits can be determined scientifically and mathematically when randomly crossing parents to create alien babies.

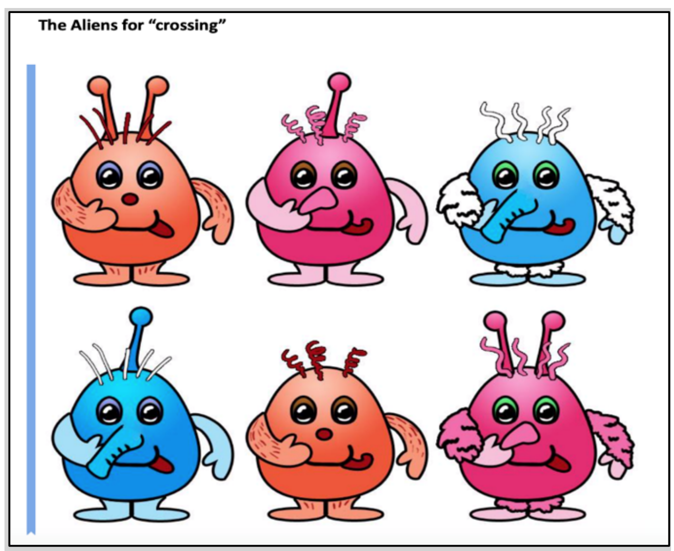


Figure 1 Alien parents

Table 3 - The Child's Genetic Make-Up

Shake the beaker to mix all of the versions! Randomly draw out different colours for each trait from the beaker so that you create complete genotypes for each trait. Remember: Each trait needs a version of the gene from "mom" and a version of the gene from "dad". As you draw out versions, write them in the "what the DNA says" columns.

Trait	What the DNA says *allele from "mom" alien*	 *allele from "dad" alien*	What we see
B. Body colour			
H. Hair colour			
M. Hair curl			
A. Antenna			
E. Eye colour			
N. Nose			
L. Hairy arms and feet			
R. Tongue roll			

Go back to **Table 1** and determine the traits of the offspring and put the information in the "what we see" column.

Figure 2 Genotype and phenotype of alien babies

After the groups drew randomly to create their alien babies, they sketched, coloured and taped their pictures to the board for their peers to identify the parents of the babies. To the surprise of the class, different sets of alien parents were suggested for each alien baby. This finding demonstrated that phenotypic information was insufficient to determine variations in traits when parent genes were crossed. Genotypic information (i.e. the alleles) was required to determine genetic variation and in turn, heredity.

1 *Nikta: Alright, what were you observing? The genes or the physical traits?* (I)
2 *Fenta: Physical traits.* (R)
3 *Nikta: Was that enough information to decide who the parents are?* (F)
4 *Class: No.* (R)
5 *Nikta: Not enough information!* (E)
6 *Nikta: When you look at what your friends wrote down, did they all agree? Did they guess the right parents for your alien baby?* (F)
7 *Class: No.* (R)
8 *Peyz: But that's weird!* (R)
9 *Nikta: So, nobody made the right guess? Is there a right answer there for you guys? Did any group get the right answer?* (F)
10 *Class: No.* (R)
11 *Tom: Did we do it wrong?* (R)

12 *Nikta: So by looking at the physical characteristics of the babies, the phenotype, it is difficult to find the parents.* (E)
13 *Nikta: What do we need that is more accurate?* (I)
14 *Peyz: We need the genes.* (R)
15 *Nikta: Yes, we need the genotype.* (E)
16 *Nikta: It's the genotype, the alleles that can help us. You are going to see how when you get to part C of the instructions and create all possible alien babies that your two parents could produce. Because now we have decided physical characteristics are not helpful. We need genotypic information- the alleles- to determine heredity.*

<u>Analysis of teaching purpose and content</u>

The purpose of this activity, including the follow-up whole class discussion, was to guide the students through a discovery and confirmation using a science experiment. The discovery was for the students to connect genetic variation with alleles in how the parents' alleles, and not the parents' physical traits, can determine the traits of the offspring. The purpose was realized in line 14 when Peyz offered his response, "*we need the genes",* and in line 16 when I revealed the answer in a presentational style. However, the "why" of the inquiry and the journey to discovery were not pursued. Some conceptual gaps needed to be addressed prior to this episode as I will explain here.

As the content was initially experimental and relatable through students' own pedigrees of phenotypic variations, the learning demands were lowered. Students navigated through the different parts of the activity with ease when investigating the phenotypes and sketching the baby aliens. However, bridging knowledge from the everyday and empirical domain to the scientific and theoretical domain was problematic as evident from Peyz and Tom's responses in lines 8 and 11 expressing confusion. The probability of certain parental alleles being passed down and determining the phenotypic traits of the offspring depending on the patterns of dominance, co-dominance and recessive was not included in the students' repertoire of everyday knowledge. The abstract entities, called *alleles*, needed to be understood in terms of general theoretical descriptions of nucleotides, as the building blocks of DNA which make up our genes, and then the patterns of dominance needed to be explained.

Examining my teaching with the lens of an analyst, I recognize that to remedy the presence of such conceptual gaps, I needed to first ensure that the language presented to the learners was comprehensible (i.e., to conduct a bottom-up approach according to the Genre Egg framework, before I pursue the inquiry). As “alleles” are abstract entities bridging the structural aspect of genes with physical variations, a clear understanding of it was important for students’ process of sense making. The student hand-out included the following description: *different versions of the same gene are called alleles.* It would have been beneficial to use the graphic organizer for *defining* (see Table 6) and ask the students to deduce from the text what “alleles” are and to write their own definitions for “alleles”, such as in Table 7 below. Consistent revisiting of the disciplinary language functions, such as *defining* would help provide the learners with a good grasp of science text sentence patterns, language functions, text types and eventually genres of various contexts (see the Genre Egg framework, Lin, 2016, p. 39). This type of bottom-up work could also help fill in conceptual gaps, such as the meaning of “alleles” and how “alleles” relate to “genes” and “variations”. Such simple pedagogical intervention (Table 7) would have been a useful teaching tool in the beginning of episode 2 to avoid confusion and losing sight of the inquiry.

Table 7 The Lexico-Grammatical Pattern for *Defining* "Alleles"

Technical Terms	Relating Verb	General Class	Phrase Giving Information
Alleles	are	genes	that determine a person’s characteristics
Alleles	are	different versions of the same gene	that control the same characteristic
Alleles	are	different versions of the same gene	that control the same characteristic resulting in variations in individuals

The same definition-giving task could then be repeated for the new science terms introduced: dominance, co-dominance, and recessive. A discussion to define such cognitively demanding key concepts would only be impactful if it was done in the context of the inquiry and involved the learners in the construction of the graphic organizers in such a way that they first deduced the definitions from the text presented to them and gradually added to their tentative definitions as they gained more knowledge in the course of the experiment. It is noteworthy that there is no fixed order to always offer definitions first or always unpack the lexico-grammar first; it is a matter of science pedagogy that fits the requirements of the task at hand. As language functions are both linguistic and cognitive, the order of presenting them should always be in response to the cognitive stage the learners to be able to receive this thinking and talking pattern.

Analysis of communicative approach and patterns of interaction

Mortimer and Scott state that different forms of discourse emerge due to various types of content. In this episode, initially, an interactive/dialogic communicative discourse emerged as I inquired about students' observations. I then made successive prompt moves, and asked questions which had "yes or no" answers in lines 3, 6 and 9. These deliberate questions were utilized to present one single perspective: that phenotypic information was not sufficient for the students to find the correct parents for the alien babies. Once I had the students' attention and their curiosity was raised around this discrepancy, there was a clear shift toward the non-interactive/authoritative dimension where I engaged in a monologue presenting to the class the scientific perspective. In other words, I accepted only one justification even though not every student had adopted this single view. Peyz's statement that the findings are weird and Tom's question of the possibility the groups had made a mistake, were ignored. I transferred the single view to the students: "*So by looking at the physical characteristics of the babies, the phenotype, it is difficult to find the parents. What do we need that is more accurate?"* But whether this was the students' point of view and whether they thought this could be a plausible explanation, was not clear. Thus, in an authoritative approach played out in an I-R-E pattern, I engaged the students in an interaction while advancing the scientific perspective deeply rooted in technical disciplinary content, outside the students' knowledge-base.

Analysis of language accommodation and TLA

This episode offered language accommodation in terms of *repeat* of some of the technical terms, such as alleles, genes, genotypes and phenotypes. Also, *reload* took place where I aimed to support the students to move beyond vocabulary by seeing the relationship between different concepts in the content: e.g. phenotypes and visible traits on the one hand, and genotypes and heredity on the other. Making connections between the ideas introduced in this episode was assisted by asking the learners to fill in the table in Figure 2, where the two columns of "allele from mom" and "allele from dad" combined into visible/phenotypic characteristic in the offspring. Figure 2 was meant to create a cognitive link between how and why our traits resemble the traits of our parents, and how and why we have traits that are different. However, the data showed that a strong link was not established as the learners expressed doubt and confusion and as I unveiled the result of the experiment in a presentation-style lecture. Per my analysis earlier, highlighting the language function of defining (Table 6), for all the new lexical items (*phenotypes, genotypes, offspring, genetic make-up, crossing* and *probability*) in this episode could have helped strengthen the links between vocabulary items and conceptual meanings as these items would be defined in context. Approaching language learning tasks by defining text-in-context is an effective teaching strategy in inquiry-based science where clues embedded in context assist students' mental functioning of newly introduced topics in a newly learned language (Lin, 2016; Mohan & Slater, 2006; Weinburgh, et al., 2014; Wu, et al. 2018).

In terms of TLA, analysis of this episode did not show teacher language awareness beyond the lexical level; for instance, identifying features of the disciplinary language and highlighting them appropriately in examples. Key concepts such as, genotypic and phenotypic information, could have been defined and compared using the typical sentence patterns useful for expressing such functions. Such a task would not have been difficult to implement as already the exchange in this episode transpired in such a comparison of phenotypes, genotypes, and the amount and accuracy of information they each offer (see lines 12 and 13). Once the students affirmed that physical traits were not sufficient information, I asked: "So, *what do we need that is more <u>accurate</u>*?" Here I was able to compare the two key concepts and highlight them for the students by posing multiple questions in order to engage the learners in interaction. However, my questions all took on the form of authoritative interventions where I carelessly ignored the big burning question. I did not guide the students to explore <u>why</u> the phenotypic information was not enough to predict the parents' genes. A comparison between phenotypic (traits) versus genotypic information (alleles) using the language features of *comparing* could have revealed to the learners the "why" of the inquiry. As Lin (2016) recommends, students need the opportunity to discover how language functions are realized in a variety of registers in order to achieve the purpose of the text. In this episode, conceptual gaps could have been filled via teaching the structures and functions of the language within discourse (inspired by the "genre-based pedagogy", Derewianka, 2011) before the learners could cognitively make connections between the type of information *traits* provide versus the type of information *alleles* provide.

In summary, in this episode, there was a lack of awareness in the areas that Andrews and Lin (2017) highlight as lesson preparation, such as taking into account learner's knowledge gaps in target language ahead of time, using target language to fill in the gaps and using examples previously decided on to appropriately contextualize learning. As a result, the data showed that the learners' perspectives of the key features of the language were unknown to me then (the teacher in the class), but more familiar to me now (the analyst who has gained more knowledge of the disciplinary language). When Peyz and Tom expressed doubts in the experiment, the space for digging deeper and thinking alternative ideas became available; however, my disregard for the students' tentative expressions authoritatively closed this space. In this case, the 'real time' challenge of responding spontaneously to language learning opportunities, as suggested by Andrews and Lin (2017) was lost. I claim that factors other than lesson preparation shortfalls, such as the high learning barrier and the lack of time also dictated the authoritative discourse which played out in this episode. Had more time been available for this activity, the significant learning barriers could have been identified and explored helping the students internalize the scientific story. In this regard, I view this whole-class discussion as terminating prematurely because 1) the teacher did not consider students' perspectives of the key language features of the lesson when planning the activity, 2) the content swiftly shifted from everyday and empirical to technical in one short activity and 3) there was urgency to transition to the next part of the activity in order to finish the lesson before the bell rang. The summary of the features of episode 2 is below:

Episode 2 Summary List: Alien Babies

Teaching Purpose	Guiding to explore via scientific experimentation and introducing the scientific story
Content	Scientific experimentation and theoretical explanation
Approach	Interactive/authoritative
Patterns of Interaction	I-R-E
Language Accommodation	*Repeat, Reload*
TLA	Lexical scaffolding

4.2.3 Episode 3: Fill in the Blanks Review

In the follow-up episode of the alien baby experiment, I decided to review the concept of heredity and couple the review episode (a fill-in-the-blanks exercise) with a grammar activity where the students' paragraph-writing skills could be enhanced. In a writing activity facilitated before the alien baby experiment episode, I had introduced the class to the genre of scientific paragraph writing, where initially a scientific definition is offered and subsequent sentences further elaborate or support the definition. In episode 3, after the students had some time to complete the fill-in-the-blanks review activity (Figure 3), I went over the students' answers for correctness and reiterated the grammar point of maintaining purpose and staying on-topic throughout a paragraph.

What is Heredity?

Heredity is the passing of ----------------- to offspring (from its ------------------- or ancestors). This is the process by which an offspring cell or organism ------------------------- or becomes **predisposed** to the ----------------------------- of its parent cell or organism. Through heredity, **variations** exhibited by individuals can accumulate and cause some species to **evolve**. The study of heredity in biology is called -------------------------. **Genetic inheritance** is a basic principle of genetics. It explains how characteristics are passed from one generation to the next. **Genetic inheritance** occurs due to genetic material in the form of ------------------------- being passed from parents to their offspring.

Figure 3 Review fill-in-the-blanks activity

1 *Nikta: Here is the definition in the first sentence: Heredity is the passing of what to offspring?* (I)
2 *Jerry: Traits.* (R)
3 *Nikta: Thank you Jerry!!! Yes, traits.* (E)
Rentaro, were you going to say the same thing? Good! (E)
Now more elaboration… This is the process by which… What is "this" referring to? (I)
4 *Peyz: Heredity.* (R)
5 *Nikta: Good! Heredity!* (E)
But in English class your teacher will tell you not to use "this" or "that" when the subject is not clear. Here the subject is clear. It goes back to the sentence before.
6 *Nikta: Remember my example: When my grandfather died, my dad …. got some money. That word was?* (I)
7 *Class: Inherit.* (R)
8 *Nikta: yes, inherit.* (E)

The paragraph is using a synonym: acquire. Inherits or acquires. Here is another helpful verb. Acquires. Write both in your notes.
[Nikta writes them on the white board].

9 *Peyz: inherit is more easier kind of. Acquire means getting?* (R)

10 *Nikta: Sure! Getting, receiving. I use acquire to say learn, acquire a new language. Learning or getting. Yeah!* (F)

11 *Nikta: I also put "predispose" in bold. I thought maybe it's a new word. Your background or your genetics makes you more likely. So, predisposed means "more likely". So, predisposed to the? What of the parents?* (I)

12 *Class: Genes. Genetics. Genotype. DNA.* (R)

13 *Nikta: Yes, all good. You can write all of those.* (E)
This text that I got, says characteristics.
[Students are fidgety and display lack of interest by having their heads down on their desks or talking to their peers. Nikta senses boredom knowing the students dislike the daily grammar exercises].

14 *Nikta: I know grammar is dry. I know you're not enjoying this. But, to be honest with you, paragraph writing is a skill you're going to need very soon. Every sentence needs to tie into the sentence before it and you're going to have to have correct main verb, subject, verb tense, etc.*

15 *Nikta: OK! Where are we now? Through heredity, Tom please, variations?* (I)

16 *Tom: "Variations" is the subject and "exhibited" is the verb.* (R)

17 *Nikta: Thank you so much! "Exhibited" that's your main verb.* (E)

18 *Exhibited. "Exhibited" means what?* (I)
[Some students mumble a bit].

19 *Nikta: What's an "exhibition"?*
[No response].

20 *Nikta: You're invited to an exhibition...* (I)

21 *Rentaro: Like, Prepared?* (R)

22 *Nikta: Prepared?* (E)

23 *Peyz: it's like...Can we say kinda like a car dealership?* (R)

24 *Nikta: Oh a car dealership! I like where you're going with that! He said "car dealership". Exhibition. What do you guys say?* (F)

25 *Fenta: Show* (R)

26 *Nikta: Show! Yes! An exhibition is a gallery, or a show, a display. But here, "exhibited" is a verb and it means "to show".* (E)

27 *Kids: Show?* (R)

28 *Nikta: Yeah! Show.* (E)

<u>Analysis of teaching purpose and content</u>

The dual purpose of this whole-class review was to 1) review and maintain students' development of the scientific story of heredity, and 2) familiarize the learners with the text genre of the science expository paragraph. As this was a review activity, the learners were ready to offer accurate or semi-accurate responses demonstrating that their subject knowledge resembled the school-science view and what was intended for them to learn as delineated in the learning sequence (Table 3). What I found was that after spending five class periods on the topic of DNA as the basis for the diversity of living things, the students had indeed internalized the newly learned knowledge reflected in the responses they volunteered. For example, in the first episode, Peyz offered the key word “traits” in replacing “ways”: *We are similar in some ways to our parents*. Five classes later, in this episode, Jerry offered: *Heredity is the passing of traits to offspring*. Jerry’s internalization of the concept of “traits” from merely a physical characteristic, or in his own words “special looking”, had evolved into his understanding of “heredity” in terms of traits, alleles and DNA.

Although the content was available to the students, the language was not yet at the students’ disposal; the fill-in-the-blanks paragraph comprised of language that utilized very high levels of disciplinary registers (i.e., words, phrases, clauses or sentence patterns). Awareness of these different layers of the Genre Egg framework, and elucidating to the learners the functions of these different layers within context, was an area that could have supported students’ orientation with science expository paragraph writing. Thereby, this less-familiar, expository, text genre increased the learning demand due to its academic text organization (sentences embedded with clauses- underlined below) and its use of low-frequency vocabulary, such as *exhibited, accumulate, evolve, occur,* etc. as exemplified below:

- Through heredity, variations **exhibited** by individuals can **accumulate** and cause some species to **evolve**.
- Genetic inheritance **occurs** due to genetic material in the form of DNA being passed from parents to their offspring.

The disciplinary features of the genre of the science textbook will gradually become well-rehearsed and familiar to the students if they are explicitly highlighted and revisited within text. My aim in this episode was not to uncover its features all at once. As discussed, such attention and orientation to language functions and sentence patterns widespread in the discipline of science are associated with higher levels of language awareness for the learners and consequently greater inner confidence. However, the aim of this particular episode was to expose the students to the particular style of expository paragraph writing, and in future lessons to conduct a compare and contrast activity between students’ own writing and the text genre of the scientific registers. This activity could then assist the students to take notice of the structure and language of a scientific text in comparison with their own growing writing skills.

Analysis of communicative approach and patterns of interaction

Consistent with the teaching purpose for this review phase of the lesson, my role recurred to checking for shared understanding using a *review rhythm* (Mortimer & Scott, 2003, p.71). The review fill-in-the-blanks activity adopted a question and answer style where I read and requested single-word answers from the students to fill in the blanks. There was no exchange of ideas or request for elaborations. This highly interactive, authoritative exchange served the purpose efficiently and accurately reviewing the scientific definition of “heredity”. In this regard, there was no real consideration of any perspective other than the school science view which placed the interactive exchange on the authoritative end of the communicative approach framework.

Short, closed chains of interaction in the I-R-E format were repeated in a fast-paced review rhythm throughout the episode as labeled on the transcript. It was clear that I was only welcoming correct answers and had a script to adhere to. Students provided the acceptable responses and other than evaluation of their answers, I did not need to adopt other forms of intervention. However, it is crucial to point out that if the students’ answers had not echoed the disciplinary views, a review lesson could have set a different rhythm other than response and evaluation. Furthermore, in light of the gaps in conceptual meaning making exhibited by the students, which I discussed in episode 2 (the alien baby experiment), there were surely many students hesitant and confused sitting among those volunteering correct answers. To ensure that confidence-building as part of internalizing legitimacy and agency was fostered, I needed to be aware to engage all of the students and not only those who volunteered their answers. Having knowledge of the content and the ability to use the language in a manner that mobilizes content, translates into success, confidence and being a science-knower for the students.

Analysis of language accommodation and TLA

To teach content and language in parallel requires attention to the different layers of the Genre Egg framework, and not just the students’ use of lexicons in the correct context and in the correct form. According to Lin (2016), the integrated approach to teaching language where language is taught in context is greatly effective where students gain awareness of all levels of science text structure. This is when the teacher is able to focus on vocabulary not in isolation, but rather in connection with the text that new vocabulary is being used in. In this manner, the learning progression takes the learners from *word* to *word group*, *sentence*, *paragraph*, *text* and finally *context*. This type of SFL approach, as also described by Rose (2010), allows for each genre of writing or speaking to be distinguished based on "sub-types" or as I previously labeled "language functions" (Lin, 2016), which helps the learners to recognize the text based on these familiar functions. For instance, *"heredity is the passing of …………..to offspring from …………its ……………or ancestors"* signals to the learners the function of *defining* according to Tables 6 and 7. It also signals a hierarchical order or an evolution when they recognize the pattern of using "from" and "to". Furthermore, highlighting the structure of an introductory sentence is useful as in many science expositions or descriptive reporting, the introductory sentence offers a definition – in this case for "heredity". This type of text analysis prepares the learners that the rest of the paragraph will be focused on this specific concept requiring unity and cohesion to stay on topic.

My students and I engaged with the text at the lexico-grammatical level (i.e., filling in the blanks) while I questioned the learners on their knowledge of the functions of the various grammatical features, such as: what is "this" referring to and why should they not use "this" or "that" in the place of a subject (line 3). This type of scaffolding was an early attempt at drawing the learners' awareness to sentence patterns and academic text types. In relation with lexical scaffolding, when the students were faced with new words, I showed genuine interest for them to apply their meaning-making processes and assist each other to define the new words. For example, I was proud of Peyz for offering "car dealership" as a connection to "exhibit" (line 23) and I probed eagerly for more of the students' ideas until Fenta gave "show" and aligned her peers with a describing word. The rich language of the discipline of science demands that teachers in adapted settings use many strategies to enrich students' vocabulary acquisition in a way that fosters acquisition of active vocabulary rather than rote memorization. There were many language modification moves based on the 5R instructional model in this episode addressing vocabulary instruction. Below I offer one example for each of the five R's:

- Replace: **acquire-** "inherit or acquire", "acquire means getting or receiving", "acquiring a new language".
- Reveal: **exhibited/exhibition-** "Exhibited… that's your main verb. Exhibited…means what?

- Repeat: **inherited-** "Remember my example: When my grandfather died, my dad …. got some money."
- Reload: **heredity-** revisiting the concept and displaying relationships between the ideas presented in the paragraph for a better understanding.
- Reposition: **this/that-** "But in English class your teacher will tell you not to use this or that because the subject is not clear. Here the subject is clear."

Although my subject matter knowledge in reviewing the concept of heredity was high, to be able to integrate both content and language teaching in one writing activity presented its challenges. My students had previously mentioned to me that their least favourite part of the class was grammar work and there were clear signs of kinesics shifts in this episode that indicated boredom (line 13). I needed to reiterate to them the importance of investing the time to dissect sentences into their subgroups, such as "subject" and "predicate", and I hoped that my justification was convincing. When there are low levels of intrinsic motivation, there is tendency for the teaching to adopt a lecture-style approach as was evident in this episode. The questions that I ask of myself after analyzing my data in episode 3 are: Did I lack the skills to creatively integrate teaching of language features into science teaching without impeding content learning or boring teacher students? How could I modify my teaching pedagogy into a more motivating approach? How could I move away from the presentational practice of teaching? A comprehensive examination of these questions will be carried out in the discussion chapter. The key features of the data analysis for this review lesson using the CA framework, language accommodation and the TLA variables are below.

Episode 3 Summary List: Fill-in-the blanks Review

Teaching Purpose	Reviewing and maintaining the development of the scientific story
Content	Generalizations of scientific explanations
Approach	Interactive/authoritative
Patterns of Interaction	I-R-E
Language Accommodation	*Replace, reveal, repeat, reload, reposition* Sentence level scaffolding: subject/predicate
TLA	Lexical scaffolding and validation of learners' knowledge

4.2.4 Episode 4: Debate

This episode was part of a lesson in response to one of the curriculum guiding questions: "how would you prepare for a debate on the pros and cons of genetically modified organisms?" During two class periods prior to the debate, the students watched a documentary called "The Animal Pharm", which investigated the controversial use of genetic modification in animals by the pharmaceutical industry. I helped the students prepare to take a stance on the issues considering all aspects of the controversy and critiquing the standpoint the documentary was taking and its biases. The students divided themselves into two groups – Mother Nature vs GMOs- and worked on their arguments and their rebuttals. The students' display of knowledge demonstrated negotiation of diverse perspectives as echoed by Mortimer and Scott (2003, p.106): "Students need to be critically aware of the different perspectives that are at issue when a social problem has a scientific component". In the debate, each group was to present their stance within a 30-second time frame volunteering one speaker for each round. The opposing team would then offer a rebuttal; they could combine their efforts and support each other in strengthening their argument by offering examples and justifications. They had 1.5 minutes to do so among their group members. The transcript of a small section of the students' debate is below:

1 *Nikta: Ok, let's go to the Mother Nature group now. Your second argument please and again you can rely on facts or appeal to emotion. Your time begins now.*

2 *Rentaro: I'm going to talk about the featherless chicken. I think the feather are protecting the skin from some [unintelligible] conditions or substance being there. It's featherless because of genetic modification. Skin is gonna be affected by something [unintelligible] in bad ways. For example, for humans, I can think that if there is something wrong with my skin, after I shave my face or something. But yeah, so hair is protecting our skin or body somehow. We can't just take away.*

3 *Nikta: Sounds like… you're saying that featherless chickens will have health problems, long-term due to their featherless skin. What do you have to say about that, GMO group?*

4 *Peyz: But they're not going to be affected, cause they're not usually held in really bad places, I dunno, some sort of dirty and stuff. They're usually held in protected places, which is clean. So it doesn't means that they have less feather it's going to be affect them. It's still going to be the same thing.*

5 *Tom: [inaudible] they keep overfeeding. [Tom is farther away from the camera].*

6 *Nikta: Overeating?*

7 *Tom: Yeah, overheating. Their [inaudible] is 300 beats per minute so if they're have so many hairs, they're keeps being smaller. Like they're just trying to grow and they're just overheating so they just keeps… like when you go to the gym having so many exercise so you're trying to lose weight. So they're going to lose weight and it does mean less food for the people.*

8 *Nikta: Thank you! That's all the time for your rebuttal. Now GMOs present their next argument.*

9 *Yasmin: To add, so okay the super salmon is a genetically modified fish and I'm [inaudible] because ummm normally salmon grows in warm water, and in winter stop… ummm the gene controlling the salmon growth ummm the fish stop growing. The new salmon grows all year. This is very good.*

10 *Nikta: Okay! So, you're saying that the salmon growing all year around means more food for humans. The Mother Nature team? A rebuttal please.*

11 *Rentaro: The nature believe that they're not growing in the winter. We don't know how it's working so we can't [unintelligible].*

12 *Leaf: Okay, we don't know what happens after humans eat… few years later…the natural balance is destroyed. We don't know if we create more and more… the balance for all naturals or what will happen.*

13 *Yuki: But, farmers have been interfering with nature for thousands of years. So what if we continue doing the same using technology?*

14 *Peyz: And also it doesn't matter. It can become a problem but it's mostly, we can still control the genes by changing the genes. Because we've already changed it once so we can change it again. It doesn't matter. If it has another problem, we can come up with another … ummm… another… ummm.*

15 *Nikta: another modification?*

16 *Peyz: Yeah, another modification. So we can like remove it.*

Analysis of teaching purpose and content

The teaching purpose of guiding the students to apply and expand on the use of the scientific view was realized in this episode where the students debated and negotiated their perspectives for and against the applications of genetic engineering. To explore the implications of modern genetics, the students needed to expand their knowledge and apply it across a range of situations. They had to consider the effects of GMOs on populations and ecosystems, as evident from their responses in lines 2, 7, 9, and 12, where GM crop and organisms, such as the featherless chicken and the super salmon were debated with regards to ethics, long-term health threats, and the answer to world hunger and malnutrition. This opportunity to be critical allowed the students to talk about the science of GMO's confidently, as a direct evidence of personal meaning making, sense making and internalization of the scientific story.

Alongside the students applying and expanding the school science view, they were also becoming fluent in the speech genre of school science debate. As a language objective, the participation in and practice of this genre of *reasoning* and *rebutting* using scientific facts as evidence was crucial. The purpose of this episode was to also satisfy this language objective. It was clear that the more vocal students participated and responded impromptu more than the quieter, more timid students; however, having to personally commit to a stance, prepare a statement, and play a part to represent their team motivated the students to rehearse their public speaking skills and practice the genre of debate.

The way the talk of the classroom evolved and dialogue flourished during the debate had much to do with the nature of the content. The subject matter and its relationship to everyday views allowed for a smaller learning demand as GMOs have been popular topics of discussion even in the most casual and non-academic circles. For example, Rentaro expressed that "*you can't just take it away*" (when discussing feathers); Yasmin stated that the new salmon grows all year and "*this is very good*"; Yuki debated that farmers have been naturally selecting for years and "*so what if we continue doing the same using technology*"; and lastly Peyz argued that once technology advances, further modifications will iron out the glitches "*because we've already changed it once, so we can change it again*". Thus, students' already heterogeneous cultural views were enlarged debating a topic that had a natural connection with their everyday lives, moral compasses, cultural or religious beliefs, problem-solving strategies, and scientific perspectives. As Mortimer and Scott (2003, p.106) put it "science offering one more perspective to be added to the 'toolkit' that students can draw upon" allows the learners to expand their views.

Analysis of communicative approach and patterns of interaction

Dialogue invited the exchange of ideas as seen throughout the debate episode, where diverse perspectives were taken up, debated, accepted, rejected, challenged and therefore legitimized via the talk of the science lesson shifting the communicative discourse to the dialogic end of the dialogic-authoritative dimension. Discourse was consistent with the teaching purpose and in this case, guiding the students to apply and expand on the use of their already-internalized scientific views called for a dialogic classroom interaction in the form of a debate where the students offered their perspectives and received feedback in the absence of evaluative teacher comments. Furthermore, discourse was consistent with the content, or as Mortimer and Scott claim: content determines discourse. The subject matter of genetic engineering of organisms and crops was relatable and everyday where the talk of the classroom debated the real-life consequences of genetic modification on human health, sustainability, the world hunger crisis, animal welfare, agricultural practices, and deeper social, cultural and economic complexities. Thus, the whole class debate on the topic of implications of GMOs adopted a dialogic discourse.

Discourse also dictated the pattern of interaction. The pattern of interactions in episode 4 generated a long chain of I-R-F-R-F unique in the manner that responses and feedbacks were offered by the students without my intervention. For instance, when in line 2, Rentaro initiated the debate by raising the importance of feathers to maintain a healthy skin for the featherless chicken; Peyz, in line 4, expressed that an optimal living condition will ensure that there would be no health threats to the featherless skin; and Tom, in line 7, offered his feedback that otherwise the feathers will cause overheating of the animal which would result in smaller body weight. Another example of the I-R-F chain was seen in line 9 when Yasmin initiated that a positive outcome of genetic engineering was the modification of the gene controlling salmon growth which allowed for all-year-around growth in the super salmon. In response, in line 11, Rentaro stated that the mechanism of action was unknown and the gene modification could have potential negative health hazards for humans of which we are presently unaware. Then, Leaf, line 12, came to Rentaro's aid and offered feedback to point out also that the natural balance of marine ecosystems would be destroyed in the long-term.

The transcript examples from episode 4 indicated that a dialogic *initiation*, *response* and *feedback* chain was dominant during the debate where the process of meaning-making with no evaluative comments from the teacher was in progress. However, this truly dialogic pattern of classroom interaction could not have occurred naturally had the disciplinary views and the scientific social language been ignored resulting in gaps in the learners' knowledge of key concepts and cross-cutting ideas. Without the help of the documentary "The Animal Pharm", students' internet research and my information sheets in preparation of the learners' presentations, the disciplinary perspectives of the scientific story would have been absent from the students' toolkit and connections across the various concepts underlying the argument would have weakened. Therefore, an authoritative introductory lesson on facts, findings, experiments and long-term impacts of genetic modification paved the way for a dialogic debate lesson to take place where students comparing their views with the scientific one helped them internalize the scientific story, apply, expand it and/or critique it.

Analysis of language accommodation and TLA

During the debate, the interactions were mainly among the students and my role was to moderate. I purposely refrained from interjecting and correcting the students' language errors or mispronunciations to give them the platform and the confidence to conduct their speeches passionately. I paraphrased their utterances as a moderator to legitimize their views and only helped occasionally with word choice (lines 6 and 15). However, although, language accommodation moves were not centre-stage during the debate, the modeling by the students and the paraphrasing on my part allowed for much *repeat, reload and reposition* of new and old terminology and for register-specific language features to be reiterated.

My TLA in facilitating this episode exhibited strong components in lesson preparation due to the following. First, I selected an informative documentary and used it both to watch and discuss the episodes while reading the transcription of the episodes ahead of the time and filling in any gaps in the students' background knowledge. The documentary was informational in teaching me and the students the implications of modern genetics, in highlighting the language of the subject matter, and in raising my awareness of key features that needed to be presented to the learners. Second, I had spent time assisting the students in the preparation of their speeches, reading over their paragraphs, revisiting with them simple and complex sentence structures, topic sentence, supporting details, etc. Thus, I was capable of shuffling between the groups knowing the content and the sequence of their presentations, which exemplified a constant awareness of the learners and of the target language from the learners' perspectives. Both of these variables checked off the box for appropriate selection of materials and tasks from Andrews and Lin's (2017) list of pedagogical components which display high TLA in lesson preparation.

Additionally, in assisting the learners with writing and preparing their presentations, I was aware to guide the learners to ensure that evidence was used to support their own arguments, and evidence was used to evaluate others' arguments. As discussed in the literature review, the language genre and discourse of argumentation need to define what constitutes argumentation in science education. For my students, access to the dominant culture and language means learning the dominant ways and the established norms. In terms of building an argument and rebutting another's, they needed to use science-based knowledge and reasoning as evidence to support and legitimize their standpoints. However, it was up to them to become active learners and critical to decipher what counted as "evidence". To make this happen, classroom conditions need to promote and nurture argumentation practices successfully among students (Duschl and Osborne, 2002). This episode (along with the earlier episodes preparing for the debate), displayed that I appropriately taught, scaffolded and mediated the key features of the structure and genre of scientific, knowledge-based argumentation. I invited the learners to engage in science processes of inquiry dialogically and critically to help them foster a sense of competency and legitimacy in presenting their standpoints and supporting them in light of evidence.

Episode 4 Summary List: Debate

Teaching Purpose	Guiding students to apply and expand on the use of scientific view
Content	Scientific explanations and generalizations
Approach	Interactive/dialogic
Patterns of Interaction	I-R-F chain
Language Accommodation	*Repeat, reload, reposition*
TLA	Strong lesson preparation and appropriate selection of material, Mediation of key features of the structure and genre of scientific knowledge-based argumentation

4.2.5 Summary of Data Analysis in Teaching Genetics

From exploring a science concept to working on and internalizing new views and perspectives, the episodes in the genetics unit took the reader through a journey moving from everyday to the technical domains. Starting with the question of "*what makes us who we are*" to "*the impacts of genetic modifications on ecosystems*", the students were able to make connections, link new pieces of knowledge to old pieces and bring their perspectives to a full circle. Here, I revisit Table 3, discussed in the introduction of this chapter, to evaluate whether I was able to guide the students through the learning sequence of this unit or not. The learning sequence progressed from the empirical causes (*our genes and our environment determine our traits*) to scientific experiments (*determining the probability of phenotypic traits based on the genetic codes, called alleles*) and to finally use GMOs as scientific proof that (*DNA is the basis for the diversity of living things*). The unit of genetics was finished and the four episodes I chose to analyze depicted the learning sequence vividly as shown in Table 3 repeated below.

Repeat of Table 3- The Learning Sequence for the Unit of Genetics

Empirical causes ↓ Scientific experiments ↓ Scientific proof	Our traits are influenced by our genes and our environment. ↓ The probability of genetic traits can be determined. ↓ Genetic variation can be utilized to create new traits in GMO's

The rhythm of the classroom discourse also moved through stages based on teaching purposes, as shown in Figure 4 on the next page. I have outlined on the figure (from top to bottom in each box) the dominant discourse, the purpose aimed to be addressed, and the inquiry question examined for each of the episodes in order from the first to the last episode. In the bottom of Figure 4, a double-headed arrow connects the episodes together, progressing from everyday content to technical content. The arrow is purposely chosen to indicate movement in both directions in order to acknowledge the rich funds of knowledge that students of minoritized languages and cultures have, which are continually drawn upon. Such funds of knowledge are in no respect inferior or elementary in comparison to those of the technical domain. Therefore, efforts to equip ELLs with criticality and awareness of both content and language of the content translate into their ability to move along the content spectrum; to draw from their experiences, learn the technical domain, revisit their old knowledge, evaluate the new knowledge and eventually make connections.

The shift in discourse is summarized as follows. In the early stages of probing students' prior knowledge and exploring their everyday views (episode 1), I successively posed questions to the students to open up the problem of *what makes us who we are*. This created a dialogic discourse in which I validated the learners' prior knowledge and revealed to them how their views closely resonated with the science perspective and language. In episode 2, the alien babies, I initially encouraged dialogic discourse to draw students' attention to the surprise element of the experiment; later I terminated the interactions by making an authoritative intervention to introduce the scientific point of view: *Alleles can determine genetic variation*. Hence, when the teaching purpose shifted to introducing and making sense of the results of a scientific experiment, the interactions became predominantly authoritative in nature. Later in a review activity (episode 3), my authoritative discourse set the tone for response-giving by the students where their answers were evaluated for accuracy accepting only those that adhered with the disciplinary views of school science. Finally, in the debate (episode 4), a dialogic discourse gave rise to open dialogue, critique and negotiation of a wide range of students' views based on their developing science identities. I have designed Figure 4 to illustrate a summary of the rhythm of the classroom discourse moving the scientific story from everyday to the technical domain while the activities addressed the teaching purposes in the four episodes.

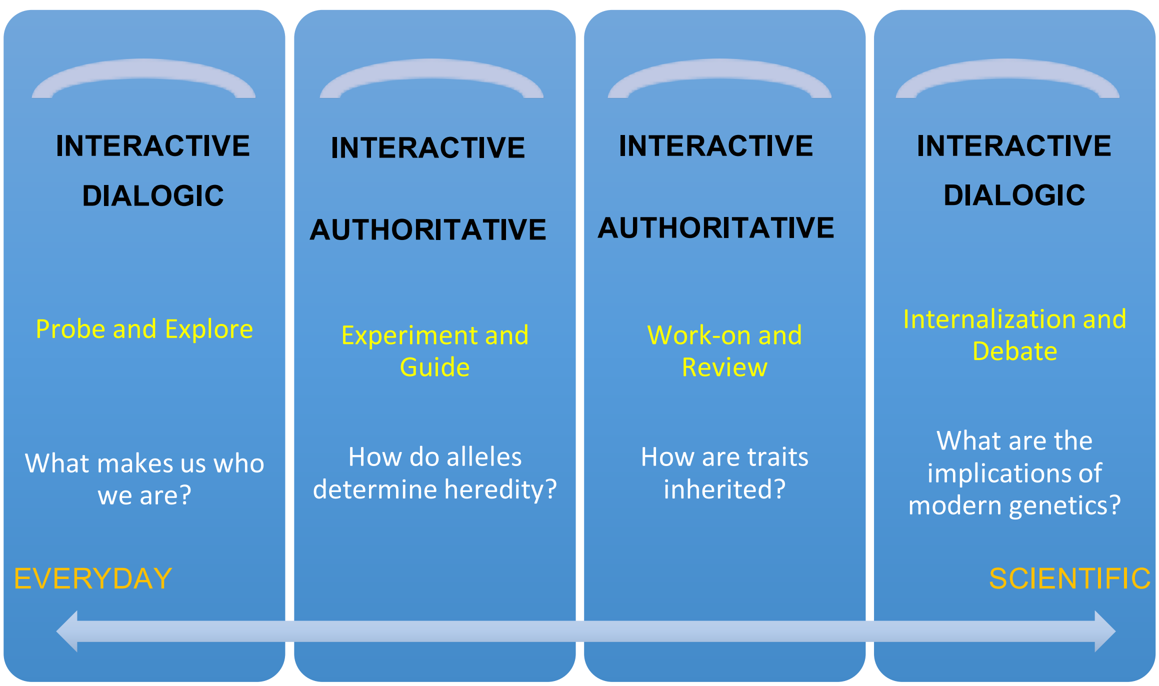


Figure 4 Rhythm of the classroom interaction in teaching Genetics

Studies have shown that the acquisition of academic language affords ELLs the means of participating in the discourse of science (Early & Kendrick, 2017; Fang & Schleppegrell, 2010; Mercuri & Mercuri, 2019; Oliveira & Weinburgh, 2019; Wu, et al., 2018). In an adapted classroom, teaching language learners, it is less likely to witness lengthy interactive discussions where students are as participative as the teacher. In my transcripts of the earlier episodes, student contributions were short and dependent on my elicitation. In the final episode of this unit where a science-related social debate was facilitated, it became noticeable that student contributions had grown in length and rigour; that the students had become more confident and willing to take risks. I trust, I was able to demonstrate that students' proficiency in the social language of school science had increased. I claim the teaching of genetics to be a successful course of integrated language and content teaching where my TLA of my students, their needs, meaning making of key concepts from their perspectives, and validation of their rich background knowledge created an environment that facilitated academic literacy growth. What is more, this same environment of respect and validation enabled a sense of empowerment on the part of the learners, where all diverse literacy practices of the students' home and background cultures were acknowledge and utilized in telling the science story while access was created to the established genres and registers. However, there were many instances in these four episodes where my TLA was limited to lexical scaffolding inadequate to build awareness of the many language functions. Besides, sentence patterns essential in science reading and science learning were absent. Had I scaffolded the learners earlier and more explicitly in noticing, rehearsing and acquiring the functions that the language of science realizes in *defining, exemplifying, classifying, contrasting, debating, reasoning* and many other functions, the learners' awareness of the language in context would have improved. These pedagogical interventions needed to take place within the context of the inquiry to ensure that the purpose of such functions along with their structures were meaningful to the students.

In the next section, I will delve into an analysis of my classroom interactions during four episodes from teaching the unit of earth science to the same group of learners in the adapted science 10 class, and I will ask the same questions in relation to patterns of communicative discourse, enhanced gains in learning the social language of the science classroom, and increased teacher language awareness.

4.3 Teaching in the Unit of Earth Science

The grade 10 earth science unit, designed by the Ministry of Education in British Columbia, prescribes the following statement as the overarching learning outcome for the students: *Energy is conserved and its transformation can affect living things and the environment*. On the Ministry's website, individual lesson objectives are stated for teachers of earth science to achieve the above learning outcome where teachers are to direct the students to answer the curriculum guiding questions (see Table 8). Content targets offer concrete and practical ways to respond to the guiding questions. I added a language target section (in bold) to modify the Macro Scaffold table for the purpose of using it in an adapted classroom.

Table 8 Macro Scaffold of Earth Science

Unit Title	**Earth Science**
Topic	Energy is conserved and its transformation can affect living things and the environment. (https://curriculum.gov.bc.ca/curriculum/science/10/)
BC Ministry Curriculum Guiding Questions	- How would you determine the structure of the Earth? - How can you use multiple sources of data to support the theory of continental drift? - How would you create a model that clearly communicates your knowledge about the Earth's energy systems? - How did first people's perspectives on energy conservation affected their ways of life? - How can you use multiple sources to demonstrate bias and assumptions about climate change?
Materials	Texts, lab equipment, games, power point, slide shows, and short films
Content target	- Students will describe Earth's energy sources including: -residual thermal energy from Earth's formation -energy from radioactive decay -solar energy (with reference to absorption and radiation in the atmosphere) - Students will study radiation and how it affects living things - Students will learn how energy transformations affect the environment positively and negatively - Students will learn about pollution, habitat destruction and carbon dioxide output - Students will compare renewable and sustainable energies - Students will explore alternative energies
Language targets	**- Students will use present tense to report on experiments. They will use past tense verbs and adverbial time to report on chronological events in the procedures of their experiments** **- Students will learn to use complex sentences and avoid Run-on's, and faulty coordination**

	- Students will use genres of description, definition-giving, classification, procedure, descriptive report, review and evaluation, reasoning/argumentation, debate, and interpretation on simple and subordinate levels **- Students will use scientific vocabulary: *density, volume, mass, the Earth's core, crust, mantle, lithosphere, biosphere, asthenosphere, plates, divergent, convergent, convection, conduction, radiation, insulation, absorption, reflection, insolation, mechanical, electrical, thermal, potential, kinetic, geothermal, renewable, sustainable, dams, tides, turbines, geothermal plants, fossil fuels, alternative energies***
Projects and assessments	Experiments & lab reports, model building, essay writing, poster project, power point presentation, debate
Interrelated mini units	1. The Earth and its structure 2. Convection currents, plate tectonics and Pangea 3. Kinetic molecular theory and thermal energy 4. The Earth's sources of energy and the energy systems 5. Energy transformations and climate change

Unlike the genetics unit which relies on learners' everyday and common-sense knowledge of their bodies, observable traits, family pedigrees, genetic disorders, genetically modified organisms and foods, etc., the unit of earth science is less firmly rooted in the everyday domain. High school students rarely have first-hand experience and exposure to how oceanic ridges and earthquakes, earth's crustal plates and mantel, the biospheres and earth's energy systems are structured and function. Therefore, conceptual gaps exist between their common-sense ways/preconceptions and the scientific/disciplinary views creating significant learning barriers. For this reason, in my data analysis, I will not use the terms *everyday* versus *technical* to differentiate the content as I did for the analysis of the genetics unit. In this section, I will utilize the terms *empirical* versus *theoretical* relation with content because topics in earth science are either experimented via simple, observable and hands-on inquires naturally or in the classroom or they are supported by theories in physics and chemistry. Hence, the theoretical nature of earth science dictates that a sound pedagogical approach be used in teaching technological literacies, such as particle theories, theories of thermal conductivity, and the kinetic molecular theory. In fact, the second curriculum guiding question, "how can you use multiple sources of data to support the theory of continental drift", sets off a learning sequence (see Table 9) which draws on students' deep understanding of theoretical, abstract, and non-tangible entities, such as particles, molecules, and energies. A teaching sequence needs to carry the students into the realm of theoretical entities and explanatory accounts of phenomena, such as the following in the case of the theory of continental drift: the kinetic molecular theory (KMT) underpins the mechanism of convection currents which in turn explains the rising of earth's layers and the theorizing of plate tectonics used as a source of data to justify the theory of continental drift. Table 9 shows this progression in conceptual development as a learning sequence in order to reach theoretical explanations for the drifting away of land masses. The table also helps illustrate the episodes as linked chains of interaction. The heavy reliance on theoretical description, explanation and generalization creates a real demand for the classroom teacher to skillfully and effectively tie the abstract theoretical entities to observable and everyday experiments and explanations. For instance, to teach convection currents, an apparatus can be used where students observe the direction of the movement of hot versus cold water; or to discuss the earth's make up, a clay ball could model the physical properties of the Earth's structure. Therefore, a smooth passage from empirical to theoretical science is required in sequencing the learning.

Table 9 The Learning Sequence to Support the Theory of Continental Drift

Theoretical Description	The Earth is composed of a crust, layers and a core.
↓	↓
Theoretical Explanation	Heat within the Earth's core forces low **density** layers to rise causing currents known as **convection currents**.
↓	↓
Theoretical Generalization	This is due to the way **thermal energy** behaves known **as kinetic molecular theory.**
↓	↓
Theoretical Description	The rising of low density layers break and move the crustal plates past each other (**the theory of plate tectonics**).
↓	↓
Theoretical Explanation	Plate tectonics explains the drifting away of land masses known as **the theory of continental drift.**

Teacher language awareness (TLA) will come into the discussion here. The realities of high school science teacher training are that training in one area is sufficient for eligibility to teach all high school sciences. This leaves many teachers unequipped and lacking knowledge of the content and the language of the subject matter to successfully teach the many branches of science such as earth science. In my case, earth science is a branch of science I did not study in post secondary education and did not train for in my teacher education program. Hence, when designing my lessons, I found myself reading, researching and educating myself on the unit's teaching objectives, at times a day ahead of the students. In the analysis of my data, I will disclose areas of both strength and weakness in my TLA in order to illuminate the relationship between this particular pedagogical awareness and the rhythm of the classroom discourse.

Furthermore, for students of adapted content courses, language instruction demands that mini language units be inserted in the flow of the lesson. Whether the language lesson is to address vocabulary or grammatical features of the registers of school science, there needs to be an instructional approach addressing the needs of this group of learners in making subject matter comprehensible and accessible to them. Therefore, the 5R instructional model along with the Genre Egg framework will be utilized once more in the analysis of my data to shed light on the necessary interventions/shifts to the rhythm of the classroom dialogue to explicitly teach the language learners vocabulary, academic functions, and genres of the technical language of science for their genuine use.

The science classroom teacher has the job of designing a thematic unit plan for each of the prescribed learning outcomes where activities, experimentations, inquiries, videos, presentations, debates, etc. are incorporated into individual lessons to guide the students to arrive at and internalize the necessary knowledge while mastering the suggested scientific language features. My approach to the design and delivery of this unit, which span over 28 class periods, was to start with the Earth; to discuss the structure of the Earth and then the Earth's sources of energy. In selecting episodes of classroom interaction to analyze, I looked for changes in teaching purpose to identify boundaries between episodes. What follows is a series of four classroom interactions, titled episodes 1 to 4, progressing respectively through the teaching purposes of 1) opening up the problem, 2) introducing the scientific story, 3) supporting internalization of new ideas, and 4) guiding students to apply the disciplinary scientific views. The first episode is chosen from the first lesson in the unit of earth science whose purpose was to open up the problem with the objective to guide the students to arrive at their own understanding of the Earth's composition. The second episode is chosen as it demonstrated the students investigating the concept of "density", where I aimed to introduce the learners to the school science view of density. In the third episode, I chose interactions which occurred during a lab, experimenting with convection cells with the purpose to guide and support internalization of the scientific view. Finally, the fourth episode was selected from the final debate lesson in earth science whose purpose was to guide the students to apply the newly learned knowledge.

Similar to the data analysis of the genetics unit, I will organize the analysis of earth science into four episodes each discussed in six sections: 1) an introduction to the teaching activity, 2) the transcript of the episode, 3) analysis of the purpose and the content objectives, 4) analysis of the communicative approach, 5) analysis of the language modifications and TLA, and 6) a summary list. A summary section will follow to encapsulate the overall themes emerging from the data in teaching the students the unit of earth science and tracking the shifts in the discourse of the classroom in attempts to move the scientific story towards a theoretical scientific discourse. A reflection on teacher language awareness will also occur where I will highlight the strengths in my TLA as well as the areas where more attention could have been given to accommodate language instruction without impeding content learning.

4.3.1 Episode 1: Earth's Composition

The prescribed learning objective suggested by the Ministry of Education in response to "*How can you use multiple sources of data to support the theory of continental drift*", first and foremost, required an understanding of the Earth's structure and composition. Thus, the purpose of the first lesson was 1) to probe what the students knew about the Earth's structure and about the concept of density and 2) to develop the science story of how density and heat play significant roles in differentiating the Earth's layers. The two parts of this episode of teaching will illustrate classroom interactions based on the above purposes.

In the first earth science lesson, I built and brought two clay balls of the same size and appearance for the students to investigate. One ball had a hollow core and the other had a golf ball placed inside of it. The objective of the lesson was for the students to inquire on all possible differences between the two balls and how physical properties such as *mass, volume* and *density* could be utilized to carry out this investigation as the external features of the two spheres did not reveal information about differences in internal composition and structure. Secondly, the connection between the clay balls and the structure of the Earth (the core and its layers with varying properties) needed to be inferred: Is the Earth one solid sphere with great consistency throughout or could it possibly have a core with drastically different characteristics and layers of varying densities? The interactions transcribed below took place while the students were investigating the balls and passing them along.

Episode 1- Part 1

1 *Nikta: Hold them [the balls] and tell me or tell your partner if you notice a difference between the balls. Pay attention to the size and other features. I like what Yuki is doing. Rattle them. Try not to poke them though.* (I)
[After six minutes, the balls have been passed around among the students. Nikta reads the title: “From clay balls to the structure of the Earth: A discussion of how physics can be used to probe Earth’s structure”.]
2 *Nikta: Probe means what?* (I)
[No response.]
3 *Nikta: Right now you’re probing. The second line after the title.*
Right now you guys are probing...grabbing the balls, weighing them, feeling their differences. (I)
4 *Rentaro: Analyzing?* (R)
5 *Nikta: Great! Asking questions. Gavin is smelling the balls. Great!* (E)
[Another five minutes pass and the students are talking in pairs.]
6 *Peyz: Did you put anything inside that?* (R)
7 *Nikta: I don’t know!* [smiling] (F)
8 *Peyz: Probably! The sun is big, but it has hydrogen inside.* (R)
9 *Tom: This is heavier.* (R)
10 *Nikta: Yes, Yuki said the yellow ball is heavier too. What about Gavin?* (F)
11 Gavin: *Size?* (R)
12 *Nikta: Size? in terms of size… is one bigger?* (F)
13 *Arvin: Do we say softer?* (R)
[Gavin says something, but he is inaudible.]
14 *Nikta: Say that again.* (F)
15 *Gavin: One of the balls… [inaudible].* (R)
[Gavin Looks at Jerry]
16 *Nikta: One of the balls doesn’t...?* (F)
17 *Jerry: Density!* (R)
18 *Nikta: Oh density! Oh! The density is?* (F)
19 *Peyz: Is higher.* (R)
20 *Nikta: So are you saying that it’s heavier because it’s more dense, Gavin?* (F)
21 *Gavin: Yeah.* (R)
22 *Nikta: Interesting! Density. That’s a good word. We can look at that.* (E)
[Nikta writes “density” on the board.]
23 *Nikta: So go ahead and tell me three reasons why one ball may be heavier than the other. One of them Gavin already gave us. That’s what Gavin is saying, basically. He’s saying more dense. Different clay. Different material. One is more dense. So it’s heavier.* (F)
24 *Peyz: Looks like this one is more flexible.* (R)
25 *Nikta: So softer?* (I)

Give me another reason why the yellow one is heavier. (I)

26 Yuki: inside. (R)

27 Nikta: Yuki? You said something inside. How can I put it into a nice sentence? The yellow ball has a ... Give me another word… a little more scientific for "inside". (I)

28 Tom: Quantum? (R)

29 Peyz: Nucleus? (R)

30 Yuki: Core! (R)

31 Nikta: Core! The yellow ball has a … what core? (F)

32 Jerry: Metal core. (R)

33 Nikta: Metal core. hmmm? Can I write a heavier core? and it could possibly be metal? (F)

One last explanation… why could the yellow ball be heavier? (I)

34 Tom: The size [uses hand gestures]. *The total thing?* (R)

35 Nikta: More material you mean? (F)

36 Peyz: what about the things that make up. Like other material? (R)

[Nikta doesn't hear.]

37 Gavin: Maybe the …. is hollow? (R)

38 Nikta: Wow! Very good. (E). *So the blue ball has a what core?* (F)

39 Gavin: H-O-L-…(R)

40 Nikta: Thank you. I'm going to put lighter and here put hollow. What if the inside of the yellow ball is empty or hollow? Good word, Gavin! (E)

<u>Analysis of teaching purpose and content</u>

The purpose of the interactions in the first part of the episode was to activate and probe students' prior knowledge of *mass, volume* and *density* as well as to help the learners apply their empirical observations to the theoretical realm of understanding the structure of the Earth. The purpose was also to introduce the scientific story in the preliminary and early stages of its development: The Earth is composed of a core and layers of varying characteristics. The comparison between the physical properties of the Earth's layers prepared the scene for a natural intervention to teach the language function of *comparing* and *contrasting* aside from scaffolding on only the lexical level. In the analysis of the TLA, I will reflect on how this task could have occurred in a meaningful way to better prepare the learners on discovering the connections between rhetorical functions and genre/purpose. Lastly, fostering students' critical thinking skills to reason and evaluate evidence in order to offer multiple solutions to the same problem was aligned with the core competencies expected to be taught in a science class.

The content of the activity, observing and describing the two clay balls, was empirical-descriptive, relying on students' senses, their everyday and general knowledge: rattling, weighing, or smelling the balls. However, in offering justifications for the differences in weight, the learners needed to draw on empirical explanations of what was causing one ball to be heavier: could it be differences in density, one having a hollow core or another having a heavier core? Thus, although, the content remained focused on an empirical-descriptive account, it can be anticipated that there would be a shift towards the abstract and theoretical in linking the clay ball to the Earth's structure. The theoretical descriptions and explanations place larger learning demands on the students as part 2 of episode 1 will reveal.

Analysis of communicative approach and patterns of interaction

As indicated on the transcript, the long chains of I-R-F-R-F with few evaluative comments were the dominant pattern of interaction. I engaged the students in a dialogic exchange to pursue the question of what could account for two balls of similar size weighing differently. The challenge of opening up the discourse in this manner is that the teacher is left with the decision of how to move towards the conventions of the scientific point of view. Offering evaluative comments to students in lines 5, 22, and 40 seemed to be the strategy I used to address this challenge. Evaluation of students' responses showed that I was able to redirect the course of the discussion towards the disciplinary views of the school science and the pre-written script in my hand. In positively acknowledging Gavin's suggestions of "density" and the possibility of a "hollow core", and Yuki's idea of "the presence of a core", I maneuvered the tension between the dialogic approach of encouraging students to make their views explicit on the one hand, and focusing more authoritatively on the accepted scientific point of view, on the other. According to Mortimer and Scott (2003, p. 53):

> The interactive dialogic communicative approach [is] not entirely open-handed. As the exchanges proceed, [the teacher] brings in her authority to bear in carrying out a preliminary sorting, or filtering, of ideas. In some cases, student views are accepted without comment… at other times [the teacher] selects part of a student answer …, which is then listed. In this way [the teacher] controls what appears on the chalkboard. The teacher's rhetoric … is that 'the aim is to collect *your* [italic in the original text] ideas and that the list of ideas on the chalkboard represents *your* [italic in the original text] suggestions'. As we can see, this is not quite the case.

In closer analysis of my data from part 1, it was clear that I also engaged with the students' ideas in a "sorting or filtering" manner where the students' perspectives were inquired upon and built into the rhythm of the discourse only when congruent with the established scientific points of view. In other words, although the communicative approach was dialogic, I had set the direction of the lesson in advance and the students' contributions were not considered with high levels of interanimation unless consistent with my lesson plan. For instance, when the students raised ideas that did not facilitate the lesson's direction- such as Peyz's response in line 8, making a reference to the Sun's core being filled with hydrogen; Arvin's inquiry about "softness" in line 13, and Tom's reference to "the size" in line 34- the ideas were met with low levels of interanimation: either ignored or merely listed and walked away from. In other instances, when responses were aligned with my pre-scripted lesson plan, they were met with high levels of interanimation, such as when scaffolding for the meaning of the word "probe" (lines 2 to 5) as well as investigating what Yuki meant by "inside" (lines 22 to 30). In these exchanges, the communicative approach was dialogic and highly interanimated, where I aimed to establish how ideas related to one another: from the idea of "inside" to the presence of a "core" and then to the possible adjectives to describe the core. In this approach, the concept of the ball no longer being a uniform entity came to life where the discourse shifted from empirical to unobservable characteristics: the core of the ball having more material, heavier material, softer material, being hollow or lighter.

In conclusion, the transcript from part 1 of this episode showed that I was committed to my pre-scripted lesson plan on telling the science story of the Earth's structure in a certain order. Whether this could be due to the nature of the content being situated far from the students' pool of everyday knowledge and experiences, or whether lack of deep content knowledge on my behalf motivated my commitment to a script, the discussion chapter will unravel the reasons for the presence of this type of sorting and filtering of students' responses in an interactive and dialogic communication and the purposes that it can or cannot serve.

Analysis of language accommodation and TLA

Drawing from the 5R model of instruction (Weinburgh & Silva, 2010), the data from part 1 used many of the moves that language teachers in content areas utilize to add to learners' inventory of functional vocabulary. *Repeat* was employed in defining the term "probe" by making references to investigating the balls in order to reveal the meaning in a hands-on manner. Rentaro offered a deeper and more all-encompassing meaning (analyzing), which allowed for *replace* to take place. In line 27, I prompted Yuki to elaborate on her response: "*Yuki? You said something <u>inside</u>. How can I put it into a nice sentence? The yellow ball has a ... Give me another word, a little more scientific for inside".* In this instance, *replace* was used in lexical scaffolding for "inside" where the students eventually suggested "core". In *replace*, the learners are becoming vocabulary analysts differentiating between everyday terms and terms that can elucidate meaning in a science context. Lastly, *replace* was also used when Gavin offered "hollow" as a way to describe why one ball was lighter than the other. Thus, slowly, throughout the interactions, the language progressed from everyday to technical: from "rattling" and "smelling the ball" to "analyzing" and "probing"; from "inside" to "nucleus" and "core"; and from "a metal core" to "a dense core". The students used empirical-descriptive language to make sense of a more technical and academic language via a newly introduced inquiry. Once more revisiting the research question of whether interruptions to address students' language needs may impede the rhythm of the discourse, the data from episode 1 indicated that this was not the case. The transcript showed that this tandem process of scaffolding on a lexical level and teaching content seemed to occur simultaneously, satisfy the purpose of activating students' background knowledge about the Earth's structure although deep meaning making of the new concepts was yet to occur. Hereby, this episode proved to be an example of concurrent teaching of content (activating prior knowledge) and language (scaffolding academic lexicon) through language-related mediation indicating high levels of TLA on a lexical level. However, the areas of low TLA, especially in orienting the learners with language functions appropriate for *descriptive* reporting in science, will also need to be considered here.

With the lens of an analyst, it is clear that in part 1 of episode 1, the interaction unfolded in such a way that I would have been able to orient the learners with two language functions: *defining* and *contrasting*. For instance, when Gavin offered "density" as a justification for the difference in the weight of the balls, I failed to probe and link Gavin's idea to the scientific definition of "density" or its formula of mass divided by volume. Requesting the learners to *define* "density" could have helped the students to make deeper connections between "size/volume" and "weight/mass" on how two balls of exact size could weigh differently. In this case, one ball was more dense; or in other words, it had more mass for the same volume. *Defining* could follow the formula presented in Tables 6 and 7 (technical term + verb + general class+ specific characteristics), which could help the students to create their own definitions for "size", "volume", "weight", "mass" and "density" based on the classroom discussion in part 1 of episode 1. In doing applying this instructional move, the space would become available for the learners to make connections between our everyday and vernacular words, "size" and "weight", and the scientific terms, "volume" and "mass" respectively. *Defining* these components could assist the learners in their understanding of the concept "density". Furthermore, I could have offered the class definitions of these terms in scientific text and ask them to compare their initial attempts with the given text. This way, not only the learners would revisit the language pattern of *defining* but also critically evaluate their work in comparison with the genre of academic text and deepen their understanding of genres of disciplinary science. I believe that such instructional interventions, raising the language awareness of the students within context, could have improved the pedagogical impact of my teaching in this episode.

Similarly, space became available for me to teach *comparing* and *contrasting* and what this lexico-grammatical linguistic pattern looks like in the context of high school science. This intervention could resemble providing the learners with key functional vocabulary, such as *than, whereas, in contrast, in comparison, unlike, but, on the other hand,* etc. along with sample sentences: *Ball A is heavier <u>than</u> Ball B, or Ball A is hollow <u>whereas</u> Ball B is dense, solid, or filled.* Similarly, Peyz's knowledge of the Sun being filled with hydrogen was an opportune moment to raise questions to ask, "what could <u>the Earth</u> be filled with?", and can we use the same formula for *contrasting* to compare the core of the Earth with the core of the Sun. Such lexico-grammatical scaffolding relevant to science language functions could assist both meaning making of concepts and familiarity with registers to which the learners are exposed in the classroom while listening, reasoning and/or researching online.

Lastly, in analyzing the data, I realized that the consideration of the students' suggestions with higher levels of interanimation could have offered deeper understandings into this inquiry. However, lacking extensive knowledge of this branch of science and being responsible to teach it to a group of senior level students had impacted my ability, committing me to my notes and dismissing others' ideas that may have been outside of the scope of what I had prepared and rehearsed. Thereby, I see that deeper explorations of ideas (e.g. the sun being filled with hydrogen, the relationship between size and volume, the meaning of density in relation to mass and volume) were absent in this classroom interaction and consequently, pedagogical goals in <u>content</u> (the

Earth has layers of varying densities) and language (how to do a *compare* and *contrast*) were not completely integrated. This finding offers evidence to highlight the link between content knowledge and teacher identity later to be discussed in the final chapter of this dissertation.

Episode 1- Part 1 Summary List: Earth's Structure

Teaching Purpose	- Vocabulary Scaffolding: building from everyday vocabulary to technical science language - Exploring and probing students' everyday ideas about weight, mass, volume and density
Content	- Empirical/Descriptive - Empirical/Explanation
Approach	- Interactive/dialogic
Patterns of interaction	- I-R-F chains
Language accommodation	- *Replace, Reveal, Repeat* - Using the sentence pattern of *contrasting*
TLA	- Lexical scaffolding to move from empirical to theoretical - Sentence pattern scaffolding

Episode 1- Part 2

The episode progressed after the hypotheses were established to account for two clay balls of the same size weighing differently. In Part 2 of the same episode, I asked the class to brainstorm on how scientists could test the hypotheses in relation to the Earth and prove which is correct, a rather daunting task not having provided any background information on geology, physical geography, or plain measuring techniques. The aim of this part of the episode was to tell the story of how geologists learned more about the Earth's structure and its composition. Whether the activity met the lesson's objectives will be the topic of discussion next. The transcript of the teacher-student interaction is below:

1 *Nikta: Give me four methods or techniques to find out which of these hypotheses are correct? Is the inside empty or is the inside a heavier core or is the material just different densities?* (I)

2 *Peyz: Weigh them.* (R)
3 *Nikta: But we know one is heavier!* (F)
4 *Tom: Can we use the function?* (R)
5 *Nikta: Function?* (F)
6 *Tom: Yeah, like p equals.* (R)
[Nikta looks confused.]
7 *Tom: Yeah function for density.* (R)
8 *Nikta: Oh, the formula for density. Mass per volume, right? P, yeah, yeah, yeah!* (F)
9 *Tom: P, m or v?* (R)
10 *Nikta: So you're saying the formula for density. Can we arrive at that end of the lesson? We'll get to volume. We'll get to measure and divide mass by volume. We'll get there.* (F)
11 *Nikta: Now give me four ways we can test which of these is true.* (I)
Can we stick something into the ball? (I)
12 *Peyz: That's what I'm saying to see inside of...* (R)
13 *Tom: Cut it up!* (R)
14 *Nikta: Cut it up? But wait, think of the ball as the Earth.* (F)
15 *Peyz: Yeah, we can't just cut it up.* (R)
16 *Nikta: But can we stick something into it. Can we drill a hole?* (F)
17 *Peyz: Measure it.* (R)
18 *Nikta: Yeah! So if we stick something inside, we can see if it's hollow inside or if it has a dense core.* (E)
[Nikta writes on the board.]
19 *Nikta: Give me two more you guys! I'm not going to suggest. Talk with your partners.* (I)
20 *Tom: Can we have a giant tank and fill with water?* (R)
21 *Arvin: Giant tank?* (R)
[Tom uses hands to show what a tub looks like.]
22 *Peyz: Are we just taking a small piece to saying the weights or … [inaudible]?* (R)
[Nikta gives the class some time.]
23 *Nikta: Two more methods to figure out if the inside of the earth is hollow or dense.* (I)
24 *Peyz: Explosives?* (R)
25 *Nikta: Ok with what? We need a device.* (F)
26 *Tom: Machine?* (R)
27 *Nikta: Ok. What machine? What about when we need to know if baby is growing healthy inside the womb?*
28 *Tom: Xray.* (R)
29 *Peyz: Scan inside of it.* (R)
30 *Tom: The drones!* (R)
31 *Nikta: The drones did you say?* (F)
[Everyone laughs.]
32 *Nikta: Pregnant women go for … what kind of testing?*
33 *Fanta: Ultrasound?* (R)
34 *Nikta: Yeah, that's it!* (E)
35 *Peyz: What are we exactly looking for?* (R)
36 *Nikta: Sorry?* (F)
37 *Peyz: I can't get what we...* (R)
38 *Nikta: Ways to test what is inside. A hollow core or a dense core?* (I)
Maybe a magnetic test? (I)

39 Peyz: Radiation? (R)

40 Nikta: Good job! (E) *Put these down and we'll talk about them. I also had to do some research about these.* (I)
[Nikta reads off her notes.]

41 Nikta: So this is what my research showed me. Sticking something into each ball, so ok but apparently, the deepest hole ever drilled into the earth is 12 km deep. (E)

42 Jerry: Russia. (R)

43 *Nikta: So considering that the top, absolute top layer, the crust is 3,000km, drilling holes will not give us clear answers. So that's number one, you can scratch it out. What's the next one? Ultrasound. What did I find out about ultrasound?*

<u>Analysis of teaching purpose and content</u>

Progressing through the story of the Earth's structure, I had decided that a meaningful introduction would start with the initial inquiry: How did scientists obtain knowledge about the Earth's composition and structure? The purpose of the episode was then to introduce and develop the scientific story of the investigation, exploration and technological triumphs. In reflecting on this episode, I see a gap where the students' background knowledge was not aligned with the inquiry asked of them. Perhaps an internet research project assigned prior to this whole class discussion could have addressed the gap. For the learners to investigate, bring to class their findings and to create a report with their partners, learning the genre of descriptive reporting while organizing, evaluating and paraphrasing their findings on the topic of the discovery of Earth's structure would have been fruitful. This is so as the content transitioned from empirical and observable, exploring the two clay balls, to theoretical and unobservable accounts of phenomena, machinery, magnetic waves, ultrasounds, and other technological interventions in discovering the formation and composition of the Earth's layers. Thereby, technical content creating greater learning barriers slowly seeped into the social language of the science classroom. To expect the students to participate in this highly information-based discussion with no prior preparation was naïve.

<u>Analysis of communicative approach and patterns of interaction</u>

The approach employed in this part of the episode was communicative, dialogic and interactive although the inquiry was not supported with helpful and sufficient background information. Thereby, the probing did not result in real exploration of the topic because the learners were unclear and expressed confusion about the objective of the question and answer period, such as in line 35, where Peyz expressed, *"what are we* *exactly looking for?"* They also offered and suggested diverse and random array of ideas indicative that they did not quite have the knowledge base on which to rely. Their suggestions were bounced to the teacher: *weighing the balls, using the formula for density, explosives, drones, placing the balls in a water tank, machines, x-rays, scanners, and radiations*. There was no clear sign as to which of the responses were accepted, rejected, or considered for further elaboration by me; contrary views were dismissed (lines 17, 20, 22, & 39) with no interanimation of ideas in this seemingly dialogic exchange.

Near the end, after a long sequence of interactions and suggestions of alternative views, I shifted from an interactive/dialogic exchange, played out in long chains of I-R-F pattern (lines 1-17 and 19-33), to a noninteractive/authoritative presentation (lines 41 and 43). To move the story forward and to adhere to the pre-scripted lesson plan, I recognized that I needed to redirect the talk of the group to focus on the material that I had prepared; hereby, centering the discourse firmly and authoritatively onto the scientific story. After line 43 of the transcript (not included in this section), a monologue commenced in a lecture style where I narrated to the class my notes on the discovery of the Earth's structure. In short, carrying out an interactive dialogic discourse did not smoothly transition the classroom talk to the accepted scientific model because the students had not been exposed to this part of the school science social language. The content was academic and heavily rested in the technical domain absent from the learners' toolkit.

Furthermore, low levels of teacher content knowledge prevented me from genuinely inviting others' perspectives and linking their views into the growing story. Pedagogical goals in teaching the Earth's structure and teaching the language used in describing machinery and methodology necessitate high levels of awareness of both the content, the language, and the learner. However, data showed that I left the learners out of the discussion and merely read my notes out loud, aiming to transfer the information to them by making an authoritative case for the scientific view: *"So this is what my research showed me"* and *"what did I find out about ultrasounds?".* PLK invites connections across differentiated speech forms, from everyday language to technical, and disciplinary discourses. The inability to draw attention to the differences between the scientific view and the students' initial and spontaneous thinking, rendered the discourse of this classroom interaction ineffective.

Analysis of language accommodation and TLA

Attending to language features was not a strong key instructional move in this part of the episode. As I now have gained better knowledge of language pedagogies than I had as the teacher at the time of the data collection, I can see that many new words were being offered, which spoke of the students' rich background knowledge. However, I did not use the favourable circumstances to highlight the new words nor did I pursue lexico-grammatical scaffolding. The aim of the activity was on information gathering, an evaluation of students' knowledge base, and presentation of new knowledge. My rigidity in delivering the lesson did not allow me to weave in language accommodation naturally and appropriately. To do so, as the analyst, I see that I needed to supplement the learners' background knowledge via a research assignment, as discussed earlier, where the learners would be guided through the process of looking for helpful information. Such a task would have to be carefully planned where key language resources that the students need along with content objectives become clearly marked in a graphic organizer. Lin (2016, p. 80) uses a curriculum mapping table to organize and introduce useful elements needed in a unit plan. I would borrow from Lin (2016) and use the curriculum mapping table to organize the research activity for the learners as outlined below:

Table 10 Outlining the Research Assignment

Content goals	Investigating the Earth's layers
Teaching/learning activities	- Reading and gathering information - Answering the what, why, and how questions
Student roles/identities	Researchers, scientists, reporters
Key vocabulary	Crust, mantle, layers, core, interior, the Earth's composition, density
Language functions and patterns	Describing, evidence giving, reasoning and reporting
Genres (to be understood and produced)	Online resources, written report

(borrowed from Lin, 2016, p. 80)

Table 10 could help the learners understand the type of information they need to research so that they can narrow down their search. To help them research useful content, I would provide a series of question: 1) what does the Earth's interior look like? 2) How did scientists discover this? And 3) why is this information important in the study of earth science? Asking inquiry-based "why" questions encourages thinking critically and engaging in reasoning or argumentation since potential answers are diverse and take into account many viewpoints. With this activity, the students would be oriented with scientific registers of *describing*, *providing evidence*, *supporting their reasoning* and *making a report or a presentation*. A guided activity integrating content and language learning, such as Table 10, has the potential to increase the learners' conceptual knowledge and awareness of the language of genres of explanation texts, argumentative writing and reporting.

Episode 1- Part 2 Summary List: Earth's Structure

Teaching Purpose	- Developing the scientific story
Content	- Technical and theoretical
Approach	- Interactive/dialogic - Noninteractive/authoritative
Patterns of interaction	I-R-F chains
Language accommodation	None
TLA	None

4.3.2 Episode 2: Syrup and Balsa Wood

In a whole class experiment, the students were asked to inquire on the outcome of heating syrup in a large beaker using a Bunsen burner for 20 minutes while two pieces of balsa wood (very light-weight) were placed on top of the syrup in the start of the heating process. Students were to record their observations in their graphic organizers every 5 minutes. The results showed that hot syrup became more fluid-like as its density lowered in relation to the wood and was no longer able to float the wood on its surface. The purpose of the experiment was an introduction to both convection as a method of heat transfer and as the driving force behind the theory of plate tectonic (see Table 9, the Learning Sequence). Syrup was to simulate the Earth's inner layers, balsa wood was to simulate the Earth's crustal plates, and the heat source was to simulate the Earth's thermal energy. Thus, the purpose realized the progression of the learning sequence through its stages (Table 9). The hands-on experimentation of bridging the observable empirical content to unobservable and theoretical facts about heat and density deep within the Earth also helped the progression of the learning sequence. The following exchange between Peyz and me took place at the end of the 20-minute observation period.

1 *Peyz: Are we done with the observations?* (I)
2 *Nikta: Yeah, twenty minutes is done.* (R)
3 *Peyz: So do we write the observation?* (I)
4 *Nikta: Yeah, exactly what you saw. We don't change the observation!* (F)
5 *Peyz: So first it* [the balsa wood] *sank?* (R)
6 *Nikta: Yeah, it sank. But not all the way to the bottom. We didn't see it in the bottom. It kind of stuck in the in-between layers.* (F)
7 *Nikta: Peyz, what do you think we're trying to make a connection to?* (F) *When you think about the Earth?* (F)
8 *Peyz: Some layers of the earth which is in the bottom, when they're getting heated up, they're getting up because they're losing density and then they're coming on top of each other and forcing another one to go down*. (R)

[He makes gestures with his hands to show overlap].

<u>Analysis of teaching purpose and content</u>

By observing the impact of heat on the density of a substance, the learners were invited to make connections to *kinetic molecular theory, thermal energy* and *convection* as a method of *heat transfer*: 1) heat energy causes particles in matter to vibrate, collide and move farther away from each other, 2) heat is transferred, through conduction, from the source of heat to the adjacent substance causing a change in the state of matter and density, and 3) the changing density forces lighter and less dense material to rise above the more dense and heavier material. Therefore, the purpose of this episode centered around the scientific principles of *conduction and convection* to be developed and worked-on by the students. Moreover, the data showed engagement with content which transformed from empirical-explanation (what causes the <u>balsa wood</u> to sink) to theoretical-explanation (what causes <u>crustal plates</u> to rise and sink). Once more, a larger leap in learning needed to take place.

In terms of the language objectives and the roles the students played as scientists, discoverers and reporters, this episode called for delineating the language functions and respective sentence patterns for making observations and *describing/reporting* what had been observed. A worksheet was provided to the students with a table to record observations for every 5-minute interval. I filled in the first three boxes to show what was expected of the students. The table is below:

Table 11 Observation Recording Table

Time	Observation
0:00	*Balsa wood is floating on top of syrup.*
5:00	*Bubbles are forming on the surface of syrup.*
10:00	*Balsa wood is starting to sink below the surface of syrup.*
15:00	
20:00	

The expectation was that the students would record their observations every 5 minutes and use the sentence pattern for making an observation by first identifying the *subject* and then adding a *predicate* to construct a complete sentence. Previous grammar-based genre exercises had familiarized the students with *subject* and *predicate*. In recording the observations, the present participle verb tense would be used and a list of verbs to describe the changes that occur when syrup is heated, would be offered (e.g. rise, sink, float, or submerge). Furthermore, the students would need knowledge of prepositions of place to clearly identify the location of balsa wood in relation to syrup. Although these grammatical features were presented in the sample sentences in Table 11, they were not explicitly taught. In reflecting on this episode as the language analyst, the many language features that needed to be explicitly highlighted in this episode become evident. A hands-on, contextual, and learner-centred approach to address this need would be essential to first discuss the scientific register of making an observation and recording data and afterwards following up with writing the observation into a coherent paragraph and reporting on the findings. In the reporting process, there would need to be an introduction to the prepositions of time for the students to be able to describe their observations according to the sequence in which the events happened, such as first, second and third or initially, afterwards, and in the end.

<u>Analysis of communicative approach and patterns of interaction</u>

The exchange in episode 2 was interactive. Peyz was curious to know if he needed to observe the experiment longer and if something new was going to happen. I took advantage of his curiosity and probed to inquire if he could apply a newly learned scientific idea in a novel context. The data shows that by observing the heating of syrup and balsa wood, Peyz was able to make deeper connections with the underlying concept of the effects of thermal energy and density change on the Earth's crustal plates. This formed a dialogic exchange where in preliminary stages, Peyz was able to use the scientific view as his own while the teacher's voice was speaking through him. A complete appropriation and internalization of science concepts was too early to be expected, but the ability to articulate many features of the school social language was already on its way as evident when Peyz (in line 8) explained the connection he observed between the experiment and the movement of matter in the Earth's interior using language that had been identified as scientific and descriptive (for example, *getting heated, losing density,* and *forcing another one to go down*).

Analysis of language accommodation and TLA

In this episode while teaching the concept of *thermal energy, convection,* and *density,* the focus was on developing the scientific story. This classroom interaction displayed an example of an episode that did not attend to language and content simultaneously: I relaxed my commitment to language and focused solely on meaning making through classroom talk. In reflecting on the data in this episode, more effective learning would demand an intervention to teach the correct use of the verbs describing the movement of balsa wood and syrup. These verbs would then be applied to describing the movement of currents deep within the Earth as Peyz stated, using his everyday language, such as "getting up" and "go down" (line 8). This was the first investigation where the class was watching the movements of "rising up" and "falling" while syrup and the light-weight pieces of balsa wood rose, cooled and sank. Either during a per-lab activity or impromptu in this episode, I needed to explicitly teach other synonymous verbs such as *rise*, *sink, float, flow, glide* and *surge* to ensure students' genuine vocabulary development. In short, simultaneous content and language teaching does not necessarily take away from attention needed for teaching science concepts when language is taught in context, in this case, the lexical scaffolding of "rising" and "sinking" during this lab.

With regards to TLA, the data showed that I skillfully planned the simulation demo that helped Peyz to link his observations to the theories that needed to unravel in describing the physical properties that theorize the impact of heat on the Earth's layers.

According to Andrews and Lin (2017), selection of material and tasks that suit learners' language needs and serve learning objectives is an indication of high TLA in lesson preparation. As the "research analyst" observing "the teacher", I see that aside from lesson design, the shift in discourse from providing short answers to Peyz's questions in an evaluative and authoritative manner to then dialogically seeking his insight about a deeper connection was effective. I see that as the teacher I had an awareness of Peyz's conceptual abilities and was able to engage him in deeper connection-making just in time and impromptu. I maximized the teaching opportunity to invite deeper thinking through the talk of the lesson and moving the science story forward. As a result, the dialogic discourse proved to be successful in allowing Peyz to apply and expand his perspective. In this move, I displayed TLA through skillful communicative language ability and an understanding of the learner's perspectives.

Episode 2 Summary List: Balsa Wood and Syrup

Teaching Purpose	- Introducing and developing the scientific story - Guiding the students to work on the scientific perspective
Content	- Empirical-explanations to theoretical-explanations
Approach	- Interactive/dialogic
Patterns of interaction	- Triadic without evaluation
Language accommodation	- None
TLA	- Appropriate selection of material and tasks - A good level of communicative language ability - An awareness of the learner - Effective use of questions to invite dialogic interaction and students' critical thinking

4.3.3 Episode 3: Convection Cells

To teach the students the concept of convection currents, I assembled an apparatus in the classroom to replicate a convection cell in the interior of the Earth. The liquid convection apparatus consisted of a rectangular glass tube filled with water and stabilized using an upright, standing clamp. Since water is clear, food dye was added to the water to make the direction of movement detectable. The apparatus and a heat source were set up as shown in Figure 5. The students were asked to first draw the apparatus in their lab reports and predict the direction of the movement of water if the glass tube had been heated as shown; and second, watch the heating process, record their observations and explain the results. This episode took place during the fifth class period in this unit, when learners had completed the balsa wood and syrup experiment; conducted an experiment mixing oil, vinegar and water to investigate relative densities, as well as measured the density of a variety of rocks. Furthermore, an activity reviewing with the class KMT had taken place. Thus, the concept of “density” was permeating into their developing scientific perspectives. The classroom interaction while the students were observing the convection cell demonstration is transcribed below.

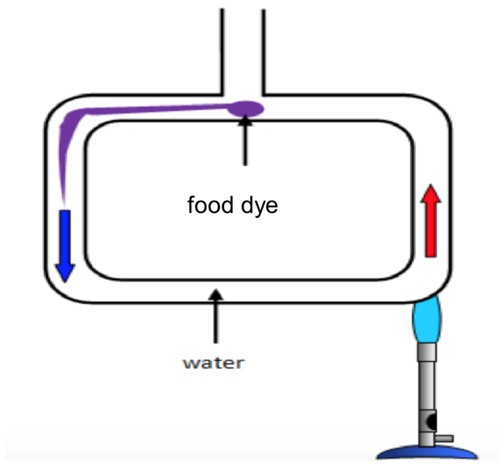


Figure 5 Apparatus used in the classroom to demonstrate a convection cell

1 *Nikta: What is happening here?* (I)
[No response]
2 *Nikta: The food dye was sitting still; now something is moving it, something is pushing it. What is that something?* (I)
3 *Tom: bubbles?* (R)
4 *Nikta: bubbles from?* (I)
[Tom is inaudible.]
5 *Nikta: We didn’t really see any bubbles in the water. Did we?* (E)
6 *Peyz: The warm water is pushing it.* (R)
7 *Nikta: The warm water is pushing it. Water is warming up- here.* (E) *So this warm water is traveling in which direction? This way or upwards?* (F)
8 *Class: Upwards.* (R)
9 *Nikta: Upwards! It’s moving upwards and it’s pushing the dye to move?* (F)
10 *Peyz: Downwards.* (R)
11 *Nikta: So this becomes the direction of our convection current.* (E) *The current moves in this direction. Why does it sink down here?* (F)

[No response.]
12 *Nikta: It's lost its? Jerry?* (F)
13 *Jerry: Its temperature.* (R)
14 *Peyz: It's lost its heat.* (R)
15 *Nikta: It's lost its heat. Correct!* (E)
Once it heats up again here, it moves upward. (E)

Analysis of teaching purpose and content

The teaching purpose for this episode was to guide the students to apply and expand on the use of the scientific view to make sense of a phenomena taking place in the demonstration. The data showed that the content was aimed to move along the empirical-theoretical dimension where the observable phenomena of water rising in the glass tube needed to be explained. This would need to rely on the theoretical underpinning of KMT explaining the change in density and hence the appearance of a convection current. At this point in the learning sequence, causal relationships needed to become key players in the talk of the school science to explain empirical and theoretical phenomena. However, this teaching episode illustrated the absence of a clear cause and effect relationship in the talk of the lesson that would substantiate the reason behind the coloured water moving in a current. When Peyz suggested in line 6, *the warm water is pushing it,* I failed to ask "why", which would review the connection between heat and movement of particles. In the absence of this connection, the content remained clouded on the cause and effect purview and was left somewhere uncertain on the empirical-theoretical dimension. Factors that could afford this episode a successful transition from the observable to the theoretical realm via utilizing a scientific causal explanation will be discussed in the analysis of the communicative approach.

In terms of language objectives, this episode displayed the opportunity to scaffold the students for the lexico-grammatical pattern to realize the language function of causal relationships pertinent to the discipline of science. Pursing the "why" of the inquiry to explain the movement of the water after being heated, would allow for producing sentence patterns in both the active and the passive voice to indicate a cause and effect relationship. However, the students would need to be explicitly taught the patterning and the lexico-grammatical features to mobilize this register convention. The students would need understanding of "active voice" (when the subject performs an action) and "passive voice" (when the subject receives an action). They would also need knowledge of linking words or logical connections, such as *because*, *due to*, *since*, and *as* used in context to convey a causal relationship. Modeling and practice of writing in this scientific register could take on a myriad of forms from exposing the learners to sample sentences, providing a fill-in-the-blanks activity, supplementing a word bank, to writing together during the activity while observing the heating and the movement of the convection current. Some sample sentences to work with are presented in Table 12 below.

Table 12 The Lexico-grammatical Pattern for Drawing a Causal Relationship

Active Voice	The water moved **because** it was heated.
	The water moved **due to** heat.
	Heat was **causing** the water particles/molecules to move.
Passive Voice	The water was moved **as** heat rose the temperature of the water.
	The water molecules were moved **because** of KMT.
	The water molecules were moved **since** heat made the molecules vibrate and collide to each other.

Analysis of communicative approach and patterns of interaction

In this episode, my initial question was met with silence. I simplified the question into smaller parts to motivate the students to volunteer their responses. The students use the school science idea that was new to them in response, but they did so in faltering and uncertain ways. This finding supported that "the new way of thinking and talking [was] still only half their own" (Mortimer & Scott, 2003, p. 114) and that the learners were still speaking through the teacher's voice. The students had not yet fully appropriated the disciplinary and technical views and their short, hesitant answers were partly due to this factor. Another factor contributing to an unsuccessful dialogic interaction in this episode was the nature of the questions I asked while probing for the students' ideas. At this point in the unit, the learners had been introduced to KMT and had knowledge of molecules colliding, moving faster and occupying more space due to a gain in heat energy. Despite having this background knowledge, in line 2 after I did not get a response to "*what is happening?",* I broke down my question into "*what is pushing the coloured water?"* The idea of "pushing" was not familiar to the learners. I believe that I would have received responses more in line with the developing scientific story had I relied on KMT where "heat causes change". I would then ask: "As water gains heat energy, what is happening to its particles?" Furthermore, when Peyz offered, "*the warm water is pushing it*", I failed to ask "how", which would allow to expand on the previously discussed idea of the movement of particles. Unknowingly, I asked the students the types of questions whose responses were limited to single words, interspersed in my delivery. The “why’s” and the “how’s” were left out of this interaction and attention was paid only to the rising and the sinking of the water creating a current.

Similarly, in line 11, I left out the discussion of the cause and effect relationship between heat and the movement of the water particles and asked about the sinking of the water. In actuality, the sinking aspect of the convection currents has to do with density; yet “density” was not mentioned once in this exchange. I asked the students, “*why does [water] sink down here”?* to explore their ideas around cooler water having more compact particles, weighing more for the same volume, and hence having greater density and therefore sinking. A modification to “*why does water sink down here?”* could have been: “what happens to the water molecules once they reach the cooler side of the tube?” Unfortunately, again the causal connection was unclear, and the learners were prompted authoritatively to answer my leading questions. The leading questions left very little space for the students to express their observations, let alone what they think caused the results.

Consequently, although, the patterns of interaction in this episode followed a dialogic chain of I-R-F-R-F as indicated on the transcript, my feedback in the form of prompts did not probe for an array of ideas. Instead, I asked the kinds of questions where the students had to guess at my intentions and make suggestions until they reach the right answer; in other words, a confirmatory exchange. The talk of the classroom did not facilitate a truly dialogic discourse since the right kinds of questions were not asked. I will tie this topic into the next section to discuss TLA and whether it is knowledge of the content or a different type of knowledge that enables the teacher in an adapted teaching environment to formulate the right kinds of questions in order to mobilize a successful dialogic discourse.

<u>Analysis of language accommodation and TLA</u>

In terms of language accommodation, episode 3 did not offer purposeful focus on language instruction. Nevertheless, with a more comprehensive knowledge of language pedagogies now than when I was teaching, I see that ample opportunities were present for me to draw the learners’ attention to features of the language of science. For instance, *repeat* and *reload* of useful verbs in describing the movement of water, such as rise, expand, lower, sink, lines 9 and 11 offered suitable openings for interjecting with a mini language lesson about such field-specific verbs. Also, teaching the key features of science language functions, the causal relationship (table 12), could have been effectively implemented in the context of the experimentation. Lastly, near the end of the episode, another teachable moment for correcting a common language error presented itself. Jerry displayed a misconception that many science students share: the difference between heat and temperature. When I asked Jerry what was lost before the water sunk down, he responded, "*its temperature*". Peyz immediately corrected him by saying, "*it's lost its heat*". A whole-class discussion using *reveal* and *reposition* could have clarified that temperature is a quantity and a way to measure heat. Thus, the degree of heat in a substance is expressed using temperature. To use temperature appropriately in a sentence, one could say, "the water temperature decreased or went down." On the other hand, "heat" is a form of energy and can transform into another form of energy or transferred to another system and therefore lost from one system to another. Thus, one could say, "the water lost its heat to the surrounding environment". I did not investigate these misconceptions whose clarifications could have offered a learning opportunity.

In analyzing my content knowledge, it is clear that the talk of the lesson in episode 3 lacked a clear direction and rigour in such a way that key features for learning (such as the "why" of the formation of the current and the "how" of the movement) were not identified. The concepts of "density" and "KMT" were left out of the discussion. Asking the types of questions that did not involve the language of science already introduced to the learners translated into random and tentative answers. The students needed content-relevant, concept-related, language-specific, and cognitively stimulating types of questions. To summarize, this episode illustrated that I did not ask the right type of questions to activate students' knowledge in order to engage them dialogically, and I did not seize the teachable moments to draw the students' attention to language features with key functions in making sense of the talk of the lesson and genre conventions. Do these two types of knowledge go hand in hand? Does lacking comprehensive knowledge of the content also reduce the teacher's ability in highlighting the language functions of cause and effect, the passive voice or field-specific verbs? In the next chapter of my dissertation, I will report on themes emerging from the data to discuss if content and TLA go hand-in-hand and how. The summary list is below.

Episode 3 Summary List: Convection Cells

Teaching Purpose	- Guiding the students to work with science meaning and supporting internalization
Content	- Empirical-explanation to theoretical-explanation
Approach	- Interactive/authoritative
Patterns of interaction	- I-R-E
Language accommodation	- *Repeat, reload*
TLA	- Selection of appropriate material and tasks pertaining to the key concept of the episode - Lack of consideration of the learning objective from the learners' perspectives - Inability to formulate inquiry questions relating to familiar and instrumental key language features

4.3.4 Episode 4: Debate

During the final class period, the students engaged in a whole-class debate. Similar with the structure of the debate episode in the genetics unit, in this episode the students placed themselves into two groups based on their stance with regards to a myriad of socially-related science questions: Will the Earth's energy run out? Can alternative energies replace fossil fuels? How do energy transformations affect the environment positively or negatively? How can you demonstrate bias and assumptions about climate change? The aim was to have the students express their points of view on the above topics drawing from scientific rules and principles covered during this unit. Each student, depending on his or her level of participation and expression of knowledge, would earn points. The group with the highest number of points would be the winning group. The series of questions that I posed also involved some of the earlier topics that the students had learned, such as the theory of continental drift. The transcript below shows the students' articulations of responses after I asked the groups to take a stance on "whether enough evidence was available to prove the theory of continental drift as scientific and valid". A second transcript will then reveal the students' engagement debating the topic of alternative energies.

I purposely chose this first part of the debate to transcribe and analyze for its continuity with episodes 1, 2, and 3 discussing the theories of plate tectonics and the continental drift. Although the transcript reveals that my questions did not generate rich responses from either group and there is evidence of a clear lack of meaning construction and critical thinking, this part of the debate can shed light on where the pedagogical strategies were inadequate and the discourse ineffective. The transcript showed that I recognized the conceptual gap and asked the groups simpler questions to help them make connections; however, the gaps persisted as seen below:

1 *Nikta: Okay, let me ask an easier question. Super easy! What scientific theory supported the theory of continental drift? It's easy cause it's in your essay.* (I)
[After 30 seconds]
2 *Nikta: Jerry would you like to take this one?* (I)
[Jerry is inaudible]
3 *Nikta: What did Jerry say? Did you guys catch that?* (I)
4 *Jerry: Convection currents.* (R)
5 *Nikta: Convection currents. Ok, let me give you a point for that.* (E)
Can you tell me more? (F)
[Jerry looks hesitant.]
6 *Nikta: Ok. What does convection mean?* (F)
[Jerry looks at his group.]
7 *Rentaro: Movement based on heat.* (R)
8 *Nikta: Jerry, you wanna say it?* (F)
9 *Jerry: Whatever he said.* (R)
10 *Nikta:* [laughing] *That doesn't count for you, though!* (F)
11 *Nikta: Anyone else? What scientific theory supported the theory of continental drift? Here, you're telling me about a phenomenon. I wasn't looking for that.* (I)
12 *Peyz: If we wanna get to that, we have to talk about something else.* (R)
13 *Nikta: Right. Gavin?* (E)
14 *Gavin:* [with some pause] *Plate tectonic.* (R)
15 *Nikta: Plate tectonic! There is the theory! Aha!* (E)
The theory of plate tectonic supports Alfred Wegner's theory of continental drift. Ok! (E). *Now, what scientific phenomenon supports plate tectonic?* (I)
16 *Peyz: So there are three examples for that.* (R)
17 *May: Three evidences.* (R)
18 *Peyz: Yeah, three evidences.* (R)
19 *Nikta: I'm not asking for pieces of evidence.* (E)
What scientific phenomenon? (I)
20 *Peyz: It can be convection.* (R)

Analysis of teaching purpose and content

The purpose of the debate was to involve students in discussion and to negotiate topics in an intellectually demanding setting where the participants needed to rely on facts and scientific knowledge to support their arguments and to refute opposing opinions. The content was rooted in the technical domain drawing from both empirical and the theoretical explanations and generalizations. Students earned points for both accuracy of their responses and for using the language of the technical scientific discourse accurately. However, the data showed that the purpose was not fulfilled; that is, student-initiated discussions displaying high levels of knowledge in the disciplinary discourse and evidence-based reasoning, a characteristic of scientific debate, did not occur. Students did not take on the role of expert or authority as debates often naturally evoke. They did not elaborate upon their ideas and only tentatively guessed at my question. For instance, when Jerry said "*Convection currents",* Rentaro intervened with an answer that caused Jerry to say "*whatever he says*" (lines 4 to 9). Only at one point, Peyz displayed elements of reasoning confidently where he suggested, "*If we wanna get to that, we have to talk about something else."* It was important to pursue Peyz's line of thinking and bring the students on board; however, Gavin had an answer and offered it right away satisfying the quest for the right answer as the teacher's institutional position in science always demands the right answers. Pursing Peyz's tentative suggestion to explore the topic could have instigated the use of *reasoning*, a useful academic register for ELLs in science to practice, which I will elaborate on later in this episode's analysis. Regardless, the episode turned into a question and answer period with evaluative feedbacks from me (lines 5, 15, and 19) in a manner that the debate could not serve its purpose.

<u>Analysis of communicative approach and patterns of interaction</u>

In a debate activity, often the responsibility is handed over to the learners. The teacher does not correct students' ideas but either asks for further elaborations or invites others to position themselves in the debate. In this episode, handing over the responsibility to the learners did not materialize in a lively debate. When my question of "whether enough evidence was available to prove the theory of the continental drift" did not provoke an answer, I took back the responsibility and posed successive elicitations. Thereby, the interactive exchange shifted the discourse to an authoritative question and answer cycle where the students replied in single word answers instead of articulations of viewpoints, and I made evaluations in place of adopting a neutral stance. The transcript for episode 4 is marked by a series of short chains of I-R-E where correct answers are praised (line 15) and wrong answers are evaluated negatively, such as "*I* *wasn't looking for that"* in line 11. If scientific ideas are not fully appropriated and internalized by the students, it is challenging for them to apply these ideas to novel situations or successfully expand on them. The absence of success in this episode could be linked to the fact that the scientific story of the Earth's structure and its theories and phenomena had not been fully mastered by the learners.

<u>Analysis of language accommodation and TLA</u>

Other than *repeat* and *reload* of field-specific, technical vocabulary in context (such as convection currents, plate tectonics, or the continental drift), there were no other purposeful accommodations of language in this concluding episode. Any attention to language functions would appropriately need to take place prior to the conclusion of the unit. As mentioned in the analysis of the teaching purpose, exposing the learners to and scaffolding for the language of debate would need to involve rehearsing evidence-based and knowledge-based reasoning sentence patterns (which I will outline in Table 13). However, the students were not foreign to the discourse of debate; they had successfully carried out a debate in the concluding lesson of the genetics unit. Therefore, in the same class period, they exhibited a good grasp of this type of discursive interaction where the topic of "renewable energies" was debated. I did not include this part of their debate in this episode's transcript because it offered very similar findings to those I obtained from the students' debate in the genetics unit. When debating clean energy sources, the students were engaged, highly participative, used evidence, facts, data and negotiation strategies to get their points across. They showed confidence, strong communication skills and subject matter expertise debating this controversial topic. A short excerpt is presented below:

1 *Nikta: Which side do you take? Renewable energies cannot replace fossil fuels. Or do you believe that actually, yeah they can. Technology can solve Earth's energy budget crisis. So which side do you sit on?* (I)
2 *Jerry: In the future or now?* (R)
3 *Nikta: Near future.* (F)
4 *Jerry: I think our renewable energy can replace fossil fuels.* (R)
5 *Nikta: Tell us why you think that.* (F)
6 *Jerry: Yeah, in the future, I think people have the ability to make enough renewable energies like electricity. There are many things that is trying to not use fossils and using the electricity like the airplane. They're trying to build an airplane that is using the energy of the electricity and also the...* (R)
7 *Nikta: You mean batteries?* (F)
8 *Jerry: Yeah the batteries and the warships now….like in France or some country,*

already using the electricity because it's got a big power more than fossil fuels. (R)

9 *Nikta: In ships?* (F)

10 *Jerry: In battle ships. So it can replace fossil fuels.* (R)

11 *Nikta: I wanna hear from Arvin.* (I)

12 *Arvin: I am agree that renewable ...* (R)

13 *Nikta: Do we say I agree or I am agree? Is it a verb or a noun?* (F)

14 *Arvin: I agree.* (R)

15 *Nikta: Good job!* (E)

16 *Arvin: Because the fossil fuels provide just 80% of our energy usage. But renewable energy just 7%. So this is a very high difference. So we cannot use [inaudible].* (R)

17 *Nikta: Oh so you disagree with Jerry. Jerry said technology will soon find amazing ways.* (F)

18 *Rentaro: So, oil is limited right? If you keep using it, you will definitely run out.* (R)

19 *And also, the 80% is the potential for renewable energies is great. So, we already have a technology to produce electricity from those wind and solar and those hydro things … so yeah we can produce more by [inaudible].* (R)

20 *Nikta: You're saying the technology is there, we just have to make it more efficient.*

The transcript above revealed that the learners were capable of negotiating socially-related science issues pertinent to renewable and sustainable energies by engaging in debate, considering contrasting viewpoints and using facts to support their arguments. The discourse of argumentation was well-rehearsed and effectively applied. There were strategies or ways of using the language to which the students resorted in order to make their argumentation impactful, such as positioning themselves in the argument, providing evidence, offering justification, defining the argument, and supporting their views with exemplification. In Table 13, I have selected from the short classroom excerpt presented above to offer examples of the students' evidence-based and knowledge-based reasoning, justification and argumentation which hinge on mobilizing recognizable sentence patterns.

Table 13 The Discursive Interactions in Debate and the Students' Examples

Positioning self in the argument	*I am agree that renewable…*
Providing evidence	*Because the fossil fuels provide just 80% of our energy usage. But renewable energy just 7%. So this is a very high difference.*
Offering justification	*Using the electricity because it's got a big power more than fossil fuels.*
Defining argument	*So it can't replace fossil fuels.*

Exemplification	*They're trying to build an airplane that is using the energy of the electricity. We already have a technology to produce electricity from those wind and solar and those hydro things.*

The sentence patterns which were found in Table 13 included the *causal relationship* (I don't believe in renewable energies <u>because</u> the fossil fuels provide 80% of our energy usage), *comparing* (electricity has got a big power <u>more than</u> fossil fuels), and *exemplification* (electricity from those wind <u>and</u> solar <u>and</u> those hydro things). According to Halliday (2004) logical semantic relations in text require that grammatical features, such as nominalization, contrasting and subordinate clauses construe rationality. Table 13 helped reveal the students' abilities to construe scientific rationality via knowledge-based reasoning in the respective grammatical structures.

The students' strengths to confidently engage in the debate, rebutting and repositioning themselves in the argument, indicated a level of empowerment and confidence in both having knowledge and having the identity of a legitimate science knower. Thereby, it can be resolved that the lack of success in the previous transcript asking the groups to provide support for the theory of continental drift lied with the nature of the questions asked. For one, a discrepancy in what defines a *theory* as opposed to a *phenomenon* could have caused confusion in answering my initial question. When I asked for a supporting theory, Jerry offered "convection currents" in line 4. In my definition, "convection currents" are a scientific phenomenon which the students observed when we heated water in the rectangular glass convection cell. However, in analyzing the data, I speculated that Jerry's answer originated in the idea of "convection currents" as a theoretical entity, unobservable and hypothesized to occur in the interior of the Earth. Later when I repeated the same question emphasizing the word "phenomenon" twice, in lines 15 and 19, Peyz answered "convection". Clearly, this was a blurry area whether "convection" as a phenomenon or a theory, both legitimate in the discipline of science, applied to the question the students were faced with. This discrepancy needed to be clarified, which could have potentially reduced the hesitation in the students' responses. Second, I speculate that the question of "*What scientific <u>theory</u> supported the theory of continental drift?"* was cognitively challenging for the students or formulated in a way that did not activate their knowledge-base on the topic.

This is a shortcoming on my part when preparing for the debate; I should have considered the target language from the perspective of the students and modified my questions. Perhaps the students had knowledge of what “plate tectonics” and “convection currents” were, but did not label them as supporting theories for the continental drift theory. Simultaneously, alertness and quick thinking, indications of high TLA, as proposed by Andrews and Lin (2017), were not sufficient in responding to students’ needs on a lexical level where I should have differentiated for them between a theory, a phenomenon and a concept. In this case, I believe that a low TLA on my behalf lead to the absence of success in carrying out a debate. Below I have summarized the teaching components for the interactions that took place when asking whether enough evidence was available to prove the theory of continental drift.

Episode 4 Summary List: Debate

Teaching Purpose	Guiding the students to apply and expand on the scientific view
Content	Technical and theoretical
Approach	Interactive/authoritative
Patterns of interaction	I-R-E
Language accommodation	*Repeat* and *reload*
TLA	None (Lack of analysis of language from the learner perspective)

4.3.5 Summary of Data Analysis in Teaching Earth Science

The classroom teacher in an adapted setting has the job of designing a thematic unit plan for each of the prescribed learning outcomes where activities, experimentations, inquiries, presentations, debates, etc. are incorporated into individual lessons to guide the students to arrive at and internalize the necessary knowledge while mastering the necessary language skills. My job was to design lessons and activities to pursue the inquiry into earth science and in the first mini unit to guide the students into an exploration of the Earth, its structure, physical and geophysical phenomena pertaining to the inquiry. As science demands experimental and hands-on teaching and as concepts in Earth Science do not resonate with students' experiences in the everyday domain, bridging of the observable and experimental with the theoretical became a key pedagogical approach. Thus, the best starting point for me was to expose the learners to empirical and observable phenomena that exist in their surroundings and later bridge their discoveries and their new views to the theoretical and abstract concepts in earth science. Bringing a clay ball as a model of the Earth, simulating plate tectonics using balsa wood on syrup and setting up an apparatus to demonstrate convection currents were aimed at teaching the students the scientific rules and asking them to apply the rules to how the Earth and its layers are theorized.

Table 9, in the introduction section of the unit of earth science depicted the learning sequence to satisfy the first prescribed learning objective: *How can you use multiple sources of data to support the theory of continental drift*? First, the structure of the Earth needed to be illustrated; second, the concept of "density" needed to underpin learning about "convection currents" which required a comprehensive understanding of KMT; third, making a link that low-density layers give rise to plate tectonics needed to be established to support the theory of continental drift. Meanwhile, building rigour in the teaching sequence meant that initial observations and descriptions made their way to explanations of causes, which could enable the eventual generalization of concepts and theories. Table 9 (copied below) depicted the learning sequence aimed at achieving the progression of conceptual learning in the first mini unit of earth science: from describing the Earth's structure and composition (in episode 1) to explaining what scientifically caused plate tectonics (episode 2) and the physics of convection currents in the Earth's interior (episode 3) to lastly theorizing generalizations about the continental drift theory (episode 4).

Repeat of Table 9- The Learning Sequence to Support the Theory of Continental Drift

Theoretical Description ↓	The Earth is composed of a crust, layers and a core. ↓
Theoretical Explanation ↓	Heat within the Earth's core forces low **density** layers to rise causing currents known as **convection currents**. ↓
Theoretical Generalization ↓	This is due to the way **thermal energy** behaves known **as kinetic molecular theory.** ↓

Theoretical Description ↓ Theoretical Explanation	The rising of low density layers break and move the crustal plates past each other (**the theory of plate tectonics**). ↓ Plate tectonics explains the drifting away of land masses known as **the theory of continental drift**.

The data in the four episodes of the unit of earth science showed a mix of interactive and non-interactive communicative approaches where discourse shifted predominantly to the authoritative end of the dialogic-authoritative dimension (see Figure 6). In episode 1, examining and making hypotheses about the two clay balls, the “sorting or filtering” of students’ ideas resulted in a dialogic interaction with low interanimation of perspectives. If the learners’ input complemented the scientific story, their views were accepted and probed for further elaboration; however, if their views lied outside the domain of the orthodoxy of science, they were dismissed. Near the end of episode 1, the scientific story of the lesson took on a technological twist where machinery and inventions into the discovery of the Earth dominated the talk. At this point, the rhythm of the episode adopted an authoritative style where I presented to the students what my research had revealed to me, lecturing by reading from my script and asking the students to take notes. In episode 2, watching the pieces of light-weight balsa wood slowly sink while the syrup was heated, the discourse maintained its dialogicity as I interacted with Peyz and encouraged him to apply his observations of the sinking of the wood to the theory of plate tectonics. Peyz demonstrated significant gains in his conceptual learning by offering a response (episode 2 transcript, line 8), which showed progression through the theoretical concepts. In episode 3, the convection cell, I resumed an authoritative approach due to my inability to employ the familiar and instrumental technical terms to which the students had been introduced. In a typical lab demo, students’ first-hand observations and discoveries have the potential to articulate and overlap organically with the scientific social language where misconceptions can be identified and used as a tool to approximate the disciplinary views. Unfortunately, data from episode 3 did not reveal deep and genuine exchanges of views due to a rigid and evaluative question and answer approach. Considering that the concept of “density” had been introduced and worked on, if the appropriate and familiar technical language was applied, the classroom interactions could have unfolded the rhythm of a review activity: interactive and dialogic. Normally, to review and summarize, teachers use “we statements”. Some of the features of “we statements” were evident in the data from this episode: "*<u>We</u> didn't really see any bubbles in the water. Did <u>we</u>?"* and "*So this becomes the direction of <u>our</u> convection current."* Thus, although the episode created a suitable environment for this kind of discursive interaction, lack of familiarity with the language of the discipline, prevented this episode to adopt a true interactive and dialogic discourse. Similarly, the evaluative question and answer approach dominated the debate which I presented in episode 4. An open-ended series of exchanges where participants take on the role of the expert and authority gave its place to tentative, single-word responses guessing at the teacher's questions. The questions constrained the flow of ideas and shifted the rhythm of the debate to an authoritative interaction.

A summary of the data presented in this chapter is illustrated in Figure 6, wherein movement from the empirical to the theoretical end of the content spectrum is indicated by a double-head arrow which I justified in section 4.2.5 (the summary of data analysis for the unit of genetics). The specific teaching purposes of each of the episodes are displayed in order to show the particular individual learning objectives of each of the episodes. The shifting rhythm of the communicative discourse is also highlighted to potentially draw connections between the communicative approach and the teaching purposes fulfilled in light of the nature of the content.

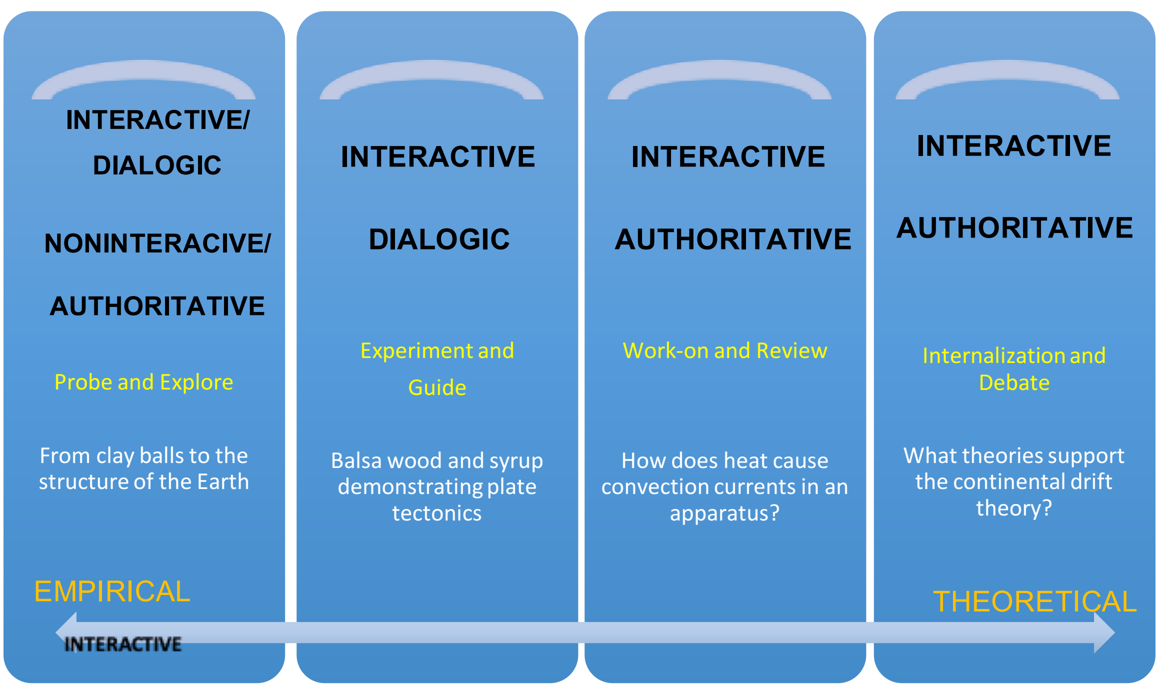


Figure 6 Rhythm of the classroom interaction in teaching Earth Science

The overall shift in the discourse to the authoritative end coupled with the students' faltering answers in the debate episode uncertain of the theory responsible for the continental drift, potentially demonstrated that a deep understanding of concepts and meaning making based on underlying connections between theories and phenomenon, in this mini unit in earth science did not occur. Asking the wrong type of questions during the debate and/or lacking content knowledge in this branch of science on my part concurrently resulted in poor scaffolding and inability to equip the learners with disciplinary content and language knowledge necessary for them to be truly involved in meaning making and conceptual grasp of the theoretical entities of earth science.

4.4 Journal Topics and Student Entries

While the classroom transcripts demonstrated advancement in language and content learning in and through discursive interactions and with the possibility for explicit teaching of scientific language functions, students' journals have the potential to illustrate gains in academic growth in students' reflections, tentative knowledge constructions and experimentations with language. Journal writing took place at the start of most class periods and span over 10 to 15 minutes. Students wrote down the question on the board and responded in a paragraph, list, a single sentence, a question or a diagram. The topics were chosen by me and served the following purposes: 1) to activate student's prior knowledge, 2) to make a connection between old and new knowledge, 3) to review a scientific concept, and 4) to develop student's critical thinking skills. Table 14 lists the journal topics assigned during the course of the two units.

Table 14 Journal Topics

	Genetics	**Earth Science**
Activate prior knowledge	- What makes us who we are? - Why do children resemble their parents? - Why do children and parents have characteristic differences? - What is DNA? - What are GMO's?	- What is Earth Science?

	Genetics	Earth Science
Make a connection between old and new knowledge	- What determines if characteristics are genetically inherited? E.g. Cancer - When is genetic variation good/useful? - When is genetic variation bad/harmful?	- How is the Earth's surface, ocean and continental crust, heated? - How can you design/make a solar water heater?
Review a key scientific concept	- Describe the structure of a DNA molecule. - How do DNA, chromosomes and genes relate to each other? - Draw a connection between DNA and proteins.	- Make a connection with the lab: What can you say about the density of the different layers of the Earth? - What caused Pangea to split? - What do you remember from the last day? - Convection currents are driven by a source of heat (hot spots deep within the Earths' core). Where does this heat (thermal energy) come from? - How are energies transferred? Give some examples like making ice-cream. - How does sea ice act as an insulator between the ocean and atmosphere? - Describe the picture. (A geothermal energy generator) - What are the main sources of the Earth's energy system? Are they sustainable, renewable, and clean? - What does renewable energy mean? - What is the difference between renewable and sustainable energy? - How does water recycle in and through the Earth's four sphere?

	Genetics	Earth Science
Develop critical thinking and reasoning skills	- Reflections on the documentary, “The Animal Pharm”. - What ethical issues matter to you? What ethical issues scientists face? - Mother nature or genetic engineering?	- Which of the renewable energy sources that you have studied, has a bigger promise to replace fuel in future?

Table 14 shows that journal topics for the two units of genetics and earth science addressed distinctly different purposes. In the earth science unit, the majority of the journal questions revolved around reviewing and articulating knowledge of a key scientific concept introduced to the students in the previous classes. Only one question fulfilled the purpose of activating students’ prior knowledge (where a question was posed before the topic was discussed in class) and only two questions required making a connection between old and new knowledge (where differences between the everyday language and the newly acquired social language of school science could be identified). Lastly, in earth science, only one journal question addressed the purpose of thinking critically and developing knowledge-based reasoning skills.

On the other hand, in the unit of genetics, reviewing and displaying conceptual knowledge of a newly-learned item was not the dominant purpose of many of the journal topics. Activating students’ prior knowledge, making connections between old and new knowledge and developing critical thinking and reasoning skills made up the majority of the questions required of students to reflect upon in their journals. It is unlikely that this discrepancy is due to the nature of the two branches of science ascertaining that they instigate different types of cognitive skills. There is no doubt that skilled, veteran teachers of earth science have many tools to engage learners in critical thinking about the structure of the earth, hypothesizing various physical and chemical theories to support geological phenomena, and to engage learners in evidence-based reasoning. Perhaps this discrepancy could be better justified with a reflection on my pedagogical content knowledge in earth science catering to more route memorization, recall and fact-checking journal questions. What is evident is that as a consequent, I made fewer cognitive demands of the students and exposed them to fewer genres in the unit of earth science than in genetics. So, first, what does this mean in terms of engagement with text? To answer this question, I will draw from a construct designed by Dalton-Puffer (2013; 2016), labeled cognitive discourse functions (CDFs), which I introduced in the literature review. Second, I will ask how do journals display internalization of new knowledge, development of cognitive strategies and acquisition of reasoning skills? In short, how did the students' journal entries display enhanced learning gains? To demonstrate students' progression in learning, I have selected journals from two of the students, Peyz and Rentaro, who were motivated learners and did not miss any classes which made it possible to use their journal entries in their entirety as data. I will first discuss Peyz and Rentaro's journal entries in genetics and then review some of their journals in earth science.

4.4.1 Journals from the Unit of Genetics

In this section, I will review three journal entries by Peyz and Rentaro. Journal #1 was composed in the beginning of the second class period after the discussion of "what makes us who we are" (episode 1 in genetics); journal #2 was written after discussing visible traits in humans and inquired on "why do children resemble their parents"; and Journal #6 was produced after the students had covered topics in both heredity and the DNA structure and asked, "what determines if characteristics are heredity". The three questions I posed in these journals fall under the category of *explaining,* where I am asking the students to give me reasons for and tell me causes of X. According to the "communicative intention" behind *explaining* that Dalton-Puffer (2016, p. 32) suggests, the students would be able to use any one or a combination of members of the CDFs, such as *reasoning, expressing cause/effect, draw conclusions,* and *deduce.* How the author unpacks the function of *explaining* is below:

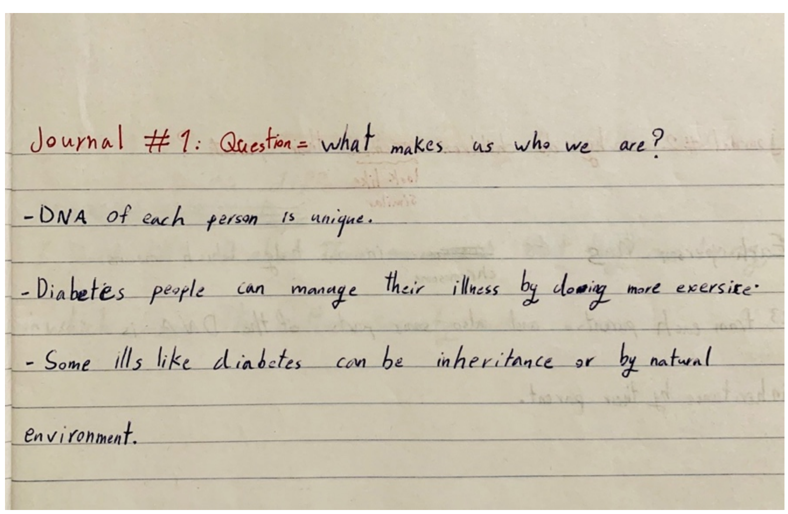
> Of the function types in the construct, EXPLAIN is probably the most complex and certainly the one with the largest extension, which makes it important to contain it for our purposes. There is actually quite a bit of literature on explaining (e.g. Stein & Kucan, 2010), something which is not the case with other elements in the CDF construct. This is both helpful but also complicated because the gaps and inconsistencies in the notion are much more visible than elsewhere. (Dalton-Puffer, 2016, p. 44, capital in original)

Although a complex function, using the CDFs as a heuristic, I will try to analyze the student's writing to see if the language function of *explaining,* via its linguistic representations, was present; that is, the students could enact suitable lexico-grammatical choices via their heightened linguistic awareness. In doing so, I am mindful that the students' awareness of these language functions was raised when they implicitly became exposed to them in text or in classroom interactions, and not through any explicit instruction of them. The findings can offer insight on whether or not these two students had familiarity with the language functions linked to subject-specific cognitive learning goals in these journals.

Furthermore, what the writing samples in the entries can show is the learners' abilities to successively internalize the newly acquired science perspectives, utilize field-specific vocabulary accurately, and employ new ideas by building upon pre-existing ones. Additionally, this kind of data has the potential to shed light on academic gains in dynamic ways as learning demands active intellectual involvement of the learners: which topics are more demanding, which preconceptions have not changed, where are the language gaps, and how have students learned to "talk science" (Lemke, 1990).

Journal Writing for Peyz in Genetics

Figure 7 presents Peyz's entries for the three journals questions in genetics where the journal questions are written in the left column and pictures of the pages of his journal notebook are pasted in the right column.

Journal #1 **What makes us who we are?**	

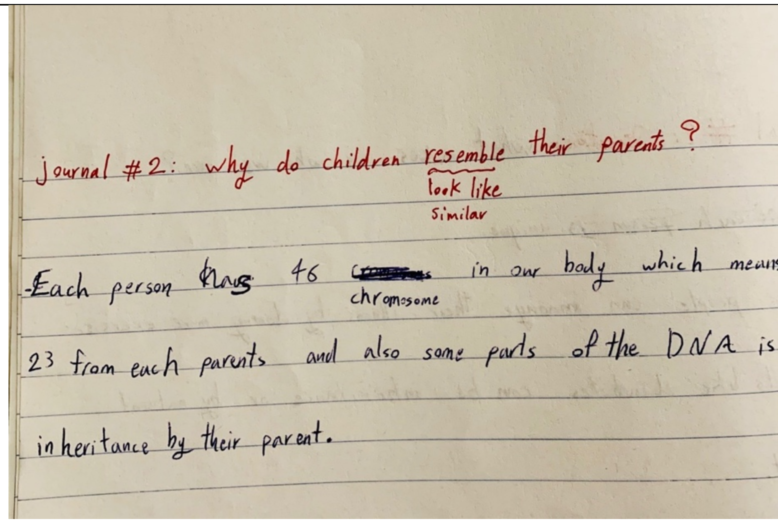
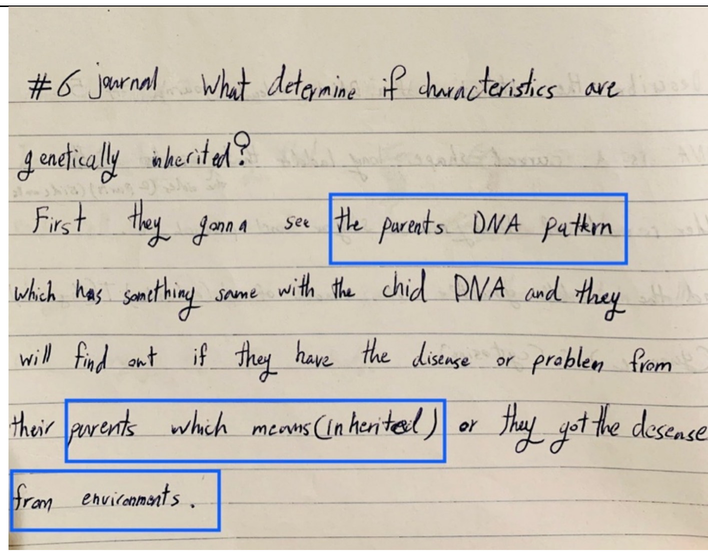
Journal #2 **Why do children resemble their parents?**	 journal #2: why do children resemble their parents? look like Similar Each person has 46 chromosome in our body which means 23 from each parents and also some parts of the DNA is inheritance by their parent.
Journal #6 **What determines if characteristics are genetically inherited?**	 #6 journal What determine if characteristics are genetically inherited? First they gonna see the parents DNA pattern which has something same with the chid DNA and they will find out if they have the disense or problem from their parents which means (inherited) or they got the desense from environments.

Figure 7 **Peyz's journals in Genetics**

The three journal topics instigated the students to explain certain relationships: 1) *What makes us who we are* (i.e., ex*plain* our relationship with our genes and our environment), 2) *Why do children resemble their* parents (i.e., ex*plain* the relationship between the parents' genes and the offspring), and 3) *What determines if characteristics are genetically* inherited (i.e., ex*plain* the passing down of genes via alleles). In analyzing the journals produced by Peyz, it is clear that the function of *explaining* influenced the cognitive and discursive patterns of his thinking/writing. Dalton-Puffer (2016) offers three main ways to represent *explaining,* for two of which I see evidence in Peyz's writing:

Table 15 Examples from Peyz's Journals Using the Function of *Explaining*

Ways to Use *Explaining* (Dalton-Puffer, 2016, p. 44)	Peyz's Examples
To make something plain or intelligible or to give details of or to unfold	*Diabetes people can manage their illness* ***by doing*** *more exercise.* *Each person has 46 chromosomes in our body* ***which means*** *23 from each parents.*
To make clear the cause or origin or reason of	***First*** *they gonna see the parents DNA pattern which has something same with the child DNA and* ***they will find out if*** *they have the disease or problem from their parents* ***which means*** *(inherited)* ***or*** *they got the disease from environments.*

In Table 15, the comparison of Peyz's journal entries with how *explaining* is enacted through cognitive and discursive patterns in the left column showed that Peyz was aware of the cognitive patterns in ways to think about specific explaining features, and that his discursive patterns were slowly taking form. The language features in bold (see Table 15) represented his discursive/cognitive patterns which were helpful in achieving the goal of *explaining* either in making something clear, expressing a cause/effect, or giving reasons. In terms of content learning, Peyz's progression in his writing showed preliminary knowledge of *genes* which he only conceptualized in terms of "DNA" without mentioning the word "genes" (in all three of his journals). He also displayed an understanding of "traits" in association with diseases, like diabetes. Furthermore, he demonstrated that he had rich knowledge in the subject matter from his very first journal by delineating that "what makes us who we are" is our DNA in interaction with environmental factors. In Table 16 (below), I compared Peyz's answers with what a typical and acceptable response in grade 10 science would look like. I did so in order to illustrate the narrowing gap between his articulation of ideas and the school science view over the course of the six class periods.

Table 16 The Narrowing Gap in Peyz' Disciplinary Literacy in Genetics

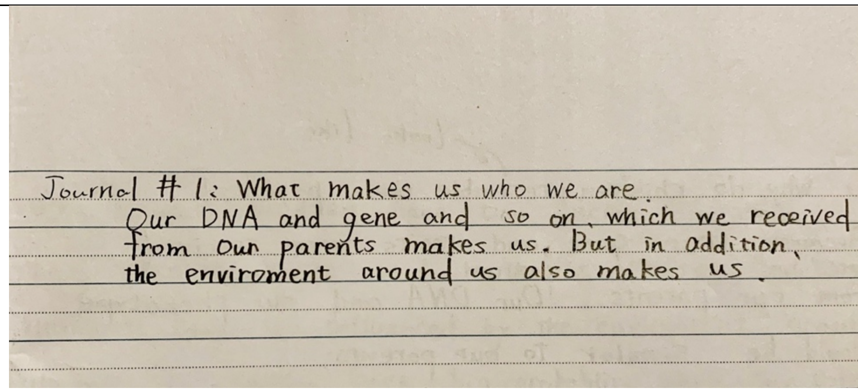
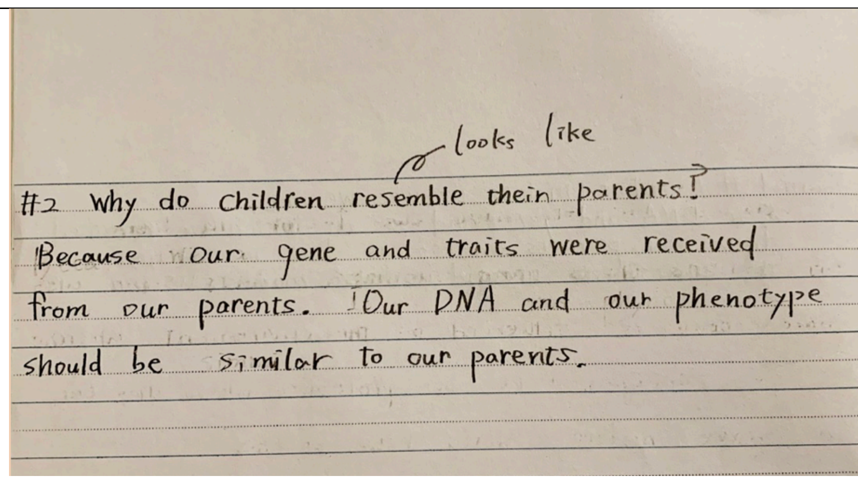
Journals	Peyz's preliminary and everyday science perspectives	School Science Perspectives
#1	*DNA of each person is unique.*	DNA is the basis for the diversity of living things.
#2	*Some parts of the DNA is inheritance by their parent.*	Children inherit genes from their parents in their DNA.
#6	*The parents' DNA pattern which has something same with the child DNA*	- Children's DNA patterns resemble their parents' DNA

Journals	Peyz's preliminary and everyday science perspectives	School Science Perspectives
	problem from their parents which means (inherited) or they got the disease from environments.	- Characteristics, such as diseases, can be genetically inherited or influenced by the environment.

In Table 16, two very clear themes revealed themselves when comparing Peyz's thought formulations with sample scientific responses: 1) Peyz's fund of knowledge on the subject matter was vast and 2) Peyz's appropriation of scientific ideas was tentative and preliminary; however, the gap was narrowing. There were great gains in Peyz's conceptual understanding as his final journal entry demonstrated his cognitive development in articulating and defining genes (or DNA) as heredity factors responsible for variations in traits, such as "disease" or "problem from parents". This knowledge was not present in episode 1 when Peyz substituted "genes" for "parents" in: *We are similar in some ways to our genes* (see transcript from episode 1 of genetics). Over the course of the six classes, Peyz had internalized the scientific definition of genes in relation to parents, offspring, alleles, traits, and variation. For example, Peyz was able to skillfully connect the two definitions of genes as 1) factors responsible for traits (in journal #1) and 2) stretches or sequences of DNA that make heredity and variation possible (in journal #2). What is more, Peyz was able to deduce a causal relationship between genes, environmental factors and traits, such that he wrote diseases can be caused by "*parents which means inherited or they got the disease from environments"* (journal #6). He thought critically and offered knowledge-based reasoning on questions posed to him by relying on newly acquired knowledge as well as his prior knowledge. Lastly, the journals provided evidence of the increasing engagement Peyz had in constructing arguments where he offered "genetic evidence" as support for determining that characteristics are inherited. Aligned with the earlier discussion about *explaining*, he employed the rhetoric of reasoning in debate: *if they have the disease or problem from their parents which means (inherited) or they got the disease from environments.* The use of "if" and "or" exemplified his understanding of this rhetoric. In terms of science-related language awareness in the context of genetics, Peyz advanced from using point-form in the first Journal to using longer sentences and constructing a short paragraph in the later journal entry, starting with "firstly" to compile knowledge-based reasons in order to develop his argument. He expanded and enriched the semantic dimensions - amidst lexico-grammatical errors- while constructing meaning via language as a tool.

Journal Writing for Rentaro in Genetics

A close look at Rentaro's first three journal entries showed that Rentaro had also advanced in both his conceptual and linguistic abilities during the first few classes in genetics. He displayed rich background knowledge in the subject matter and matured in his skills offering argument-driven explanations and reasoning which highlighted critical thinking competency in his language of science. Figure 8 shows Rentaro's responses to the same journal questions.

Journal #1 **What makes us who we are?**	 Journal #1: What makes us who we are. Our DNA and gene and so on, which we received from our parents makes us. But in addition, the enviroment around us also makes us.
Journal #2 **Why do children resemble their parents?**	 #2 Why do children resemble (looks like) their parents? Because our gene and traits were received from our parents. Our DNA and our phenotype should be similar to our parents.

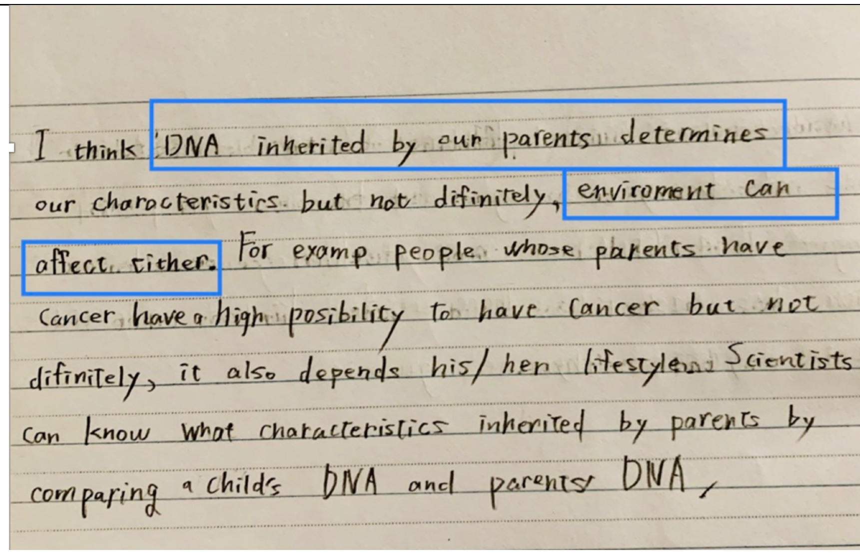
Journal #6 **What determines if characteristics are genetically inherited?**	 I think DNA inherited by our parents determines our charocteristics but not difinitely, enviroment can affect either. For examp people whose parents have cancer have a high posibility to have cancer but not difinitely, it also depends his/ her lifestyle. Scientists can know what characteristics inherited by parents by comparing a child's DNA and parents' DNA,

Figure 8 Rentaro's journals in Genetics

I will apply the same type of analysis in investigating Rentaro's awareness and application of the CDFs. The journal questions asked of him to *explain* his thinking and use language to display his thinking. Table 17 represents his efforts in comparison with the ways *explaining* is typically realized in the discipline of science.

Table 17 Examples from Rentaro's Journals Using the Function of *Explaining*

Ways to Use *Explaining* (Dalton-Puffer, 2016, p. 44)	Rentaro's Examples
To make something plain or intelligible or to give details of or to unfold	*Our DNA and genes and so on which we received from our parents makes us.* ***But in addition****, the environment around us* ***also*** *makes us.*
To make clear the cause or origin or reason of	*Scientists* ***can know*** *what characteristics inherited by parents* ***by comparing*** *a child's DNA and parents' DNA*

In the instrumental words and phrases which I have written in bold in Table 17, it became clear that Rentaro was able to use thinking/writing to enact the function of *explaining* according to the ways suggested in the left column of the table. "In addition" and "also" were used to give details and unfold while "can know" and "by comparing" were used to make clear his reasons. The cognitive function of *explaining* was present in Rentaro's repertoire of language knowledge and was being worked on here in his attempts to explain his cognition in his journals.

It is evident that Rentaro's writing was gaining rigor and fluency both in elaborating on concepts and increasing in length of writing and complexity of sentence structures. Initially, Rentaro used a group of words related to genetic inheritance, such as “genes”, “DNA”, “traits”, and “phenotypes” interchangeably; perhaps because these words are often used incorrectly in everyday speech. At this early stage of exposure, Rentaro had the ability to use the words in the correct context but was not able to de-cluster the words to use them in specific and appropriate context. It is also possible that he had been exposed to these words in his L1 and could transfer them to English but hesitantly. Moreover, it is also plausible that being a language learner, he was using his electronic dictionary to translate the words from his L1 to English and was retrieving synonymous terms. To further analyze Rentaro's development of disciplinary literacy, I have drawn a comparison between his writing in his journals with acceptable and typical answers to the same questions found in main-stream science (see Table 18).

Table 18 The Narrowing Gap in Rentaro's Disciplinary Literacy in Genetics

Journals	Rentaro's preliminary and everyday science perspectives	School Science Perspectives
#1	*Our DNA and gene, in addition the environment around us make us.*	Together our genes and our environment make us who we are.
#2	*Our genes and our traits were received from our parents. Our DNA and our phenotype should be similar to our parents.*	Children inherit genes from their parents in their DNA. Therefore, their phenotypes and genotypes resemble those of their parents.
#6	*DNA inherited by our parents determines our characteristics.* *Environment can affect either.* *By comparing a child's DNA and parents' DNA.*	Genetic inheritance occurs due to genetic material, in the form of DNA expressing certain genes, being passed from parents to their offspring.

In journal #1, Rentaro listed DNA and genes as factors responsible for making us who we are; an acutely close articulation in comparison to the disciplinary language. He displayed awareness of genes as complex biological blue prints when he used the phrase “*but not definitely”* twice in journal #6 to express the intricate involvement of other factors in inheritance of diseases, which is echoed also in the disciplinary perspectives. Rentaro was developing his own story in parallel with the scientific perspective and being critical in his journey. A comparison of his responses next to the acceptable scientific language (in Table 18) revealed a narrowing gap in Rentaro's internalization of the social language of school science. The final journal was evidence for Rentaro exchanging the novice scientific understandings for more nuanced understandings and articulation in using the relevant terms to make connections between the DNA of the offspring to the parents' DNA, not in its simple meaning of heredity but as a tool into the discovery of genetic inheritance. Rentaro had utilized his rich prior knowledge where causal relationships were already established. In a short amount of time, he had been able to use examples like cancer as evidence of traits that may be influenced by genes or by the environment, in order to argue that characteristics cannot be determined to be genetics using a simple formula. Furthermore, Rentaro's lexico-grammatical errors did create sources of confusion in meaning. For example, in journal #6, he mistakenly used the preposition "by" instead of "from" when he wrote "DNA inherited by our parents determines our characteristics". Such lexico-grammatical errors did not hinder Rentaro's meaning from being conveyed clearly, but offered opportunities for feedback and revision via this written form of communication.

Reviewing of students' journals and highlighting areas of weakness in lexical or grammatical features could greatly benefit ELLs in adapted science. Similarly raising the adapted teachers' linguistic knowledge via register and genre-based pedagogies in order to teach the functions of *explaining, descriptive reporting, classification, exemplification, argumentation* or many other useful discourse functions in science to the learners would iron out many of the grammatical errors in word choice and sentence structure which were present in Rentaro's and Peyz's journal entries.

Summary of the Journals in Genetics

At first, it may seem that a comparison of Peyz and Rentaro's writing with the generally acceptable school science perspective is contradictory to the belief that science learning requires developing alternative ways of talking and thinking about the natural world. It may seem that I intended to have the students in my adapted science class all parroting the same language. However, my intention was not this. I believe that comparing student views with the scientific views helps learners make sense of the scientific story where their everyday thematic patterns or concepts can foster the development of the scientific story towards a theoretical scientific discourse in a manner that they can be aware and critical of what resides with their inherent beliefs and what contradicts them. Then they are equipped with the right tools to view the contradictions and make sense of them.

Furthermore, for the few journals reviewed here, it seems that successful learning was achieved. Could this be due to the nature of the content leading to a relatively smooth passage from everyday to scientific views? Or was it because many dialogic interventions were incorporated into the talk of the lessons in each preceding class before the journal questions were asked? The potential relations between these factors deserve a thorough review, which is beyond the scope of my research. For now, I conclude that the objective of the first few lessons in genetics was achieved: Peyz and Rentaro ended up with a generalized and technical description of traits in response to genetic inheritance, while becoming more fluent in the speech genre of school science, especially in *explaining* and *reasoning*.

4.4.2 Journals from the Unit of Earth Science

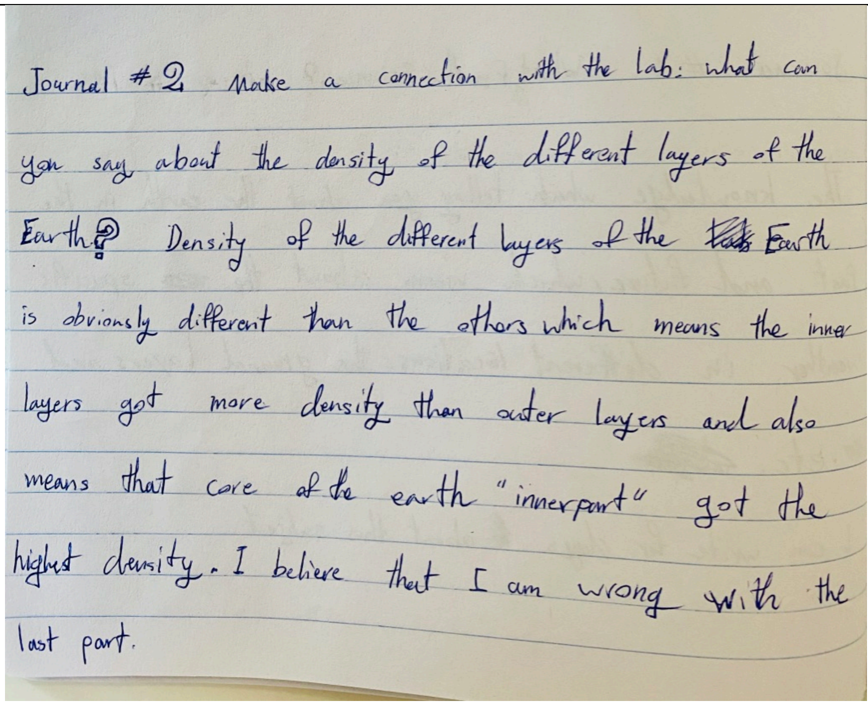
The objective of the initial lessons in earth science was to build a logical flow of the conceptual understanding where students could draw connections between the following ideas: the Earth has a layered structure, the different layers of the Earth have varying densities, and density changes due to temperature. If students were able to build those connections then the second set of ideas around thermal convection and plate tectonics could flow logically: when rocks in the interior of the Earth are heated, their density decreases and they rise; rising material causes convection currents which can break a continent apart and force the pieces in opposite directions known as plate tectonics. Students could then make connections between the theory of plate tectonics and what Alfred Wegner called the continental drift theory, the splitting of a landmass known as Pangea into the seven pieces of land we call continents today. To examine whether this flow of ideas made logical connections for the students, I have selected four of Peyz's and Rentaro's journal entries. I will discuss them in more detail to bring light to the two students' science literacy development and conceptual understanding of the topics. Similar to the last section, I will borrow from the cognitive function types present in science and delineated by Dalton-Puffer (2013; 2016) to deduce what the learners were able to accomplish; again, being mindful that the students were not explicitly taught the linguistic structures in mapping the functions.

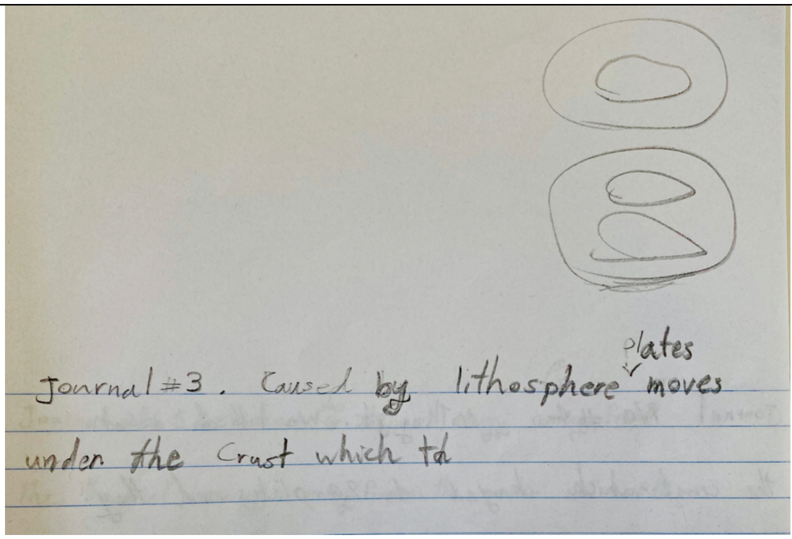
Three of the questions posed to the students in the journals I have chosen, required of them to think and write in order to realize the function of *describing* and/or *classifying*. The CDF members for these two function types encompass: *label, identify,* *name, specify, compare/contrast, match* and *categorize* (Dalton-Puffer, 2013; 2016). The questions are as follows: What can you say about the density of the different layer of the Earth? (i.e., *describe* and/or *classify* the layers of the Earth), what do you remember about the continental drift theory? (i.e., *describe* the continental drift theory), and where does the Earth's thermal energy come from? (i.e., *describe* and/or *classify* the sources of Earth's thermal energy). Only one question has required the function of *explaining*: What caused Pangea to split? Interestingly, this is the one question for which the two students did not provide much thought/text. As I mentioned in the introduction to this section, less complex cognitive tasks were asked in the earth science journal questions as opposed to the questions for journal writing in genetics. *Explaining* in comparison with *describing* or *classifying* makes complicated cognitive requirements. *Describing* and *classifying,* most often but not always, are satisfied by means of rote memorization and regurgitation. I will use the students' examples to show their successes and failures in addressing the language functions asked of them to perform in answering the journal questions.

<u>Journal Writing for Peyz in Earth Science</u>

Figure 9, below, shows how Peyz responded to the four questions posed to him in earth science. The unit of earth science commenced in March, six months after the first journal was written in genetics. It is obvious that his writing has grown in length. He used the first-person pronoun to claim his ideas and reasons; and other than journal #3, his paragraphs were composed of tentative introductory sentences and some concluding thoughts. As journal writing adopted a casual and student-driven communication approach, Peyz used the platform to reflect, ask questions, test his ideas and draw to assist him in making sense of the Pangea question (journal #3) which required connecting the physical aspects of the structure of the Earth with thermal and geothermal properties of Earth's energy systems. Peyz' four journals are below; the questions are written in the left column and pictures of his journal notebook are pasted into the right column of Figure 9.

<table>
<tr><td>Journal #2:

Make a connection with the lab. What can you say about the density of the different layers of the Earth?</td><td>
Journal #2 Make a connection with the lab: what can you say about the density of the different layers of the Earth? Density of the different layers of the Earth is obviously different than the others which means the inner layers got more density than outer layers and also means that core of the earth "innerpart" got the highest density. I believe that I am wrong with the last part.</td></tr>
<tr><td>Journal #3:

What caused Pangea to split?</td><td>
Journal #3. Caused by lithosphere plates moves under the crust which ta</td></tr>
</table>

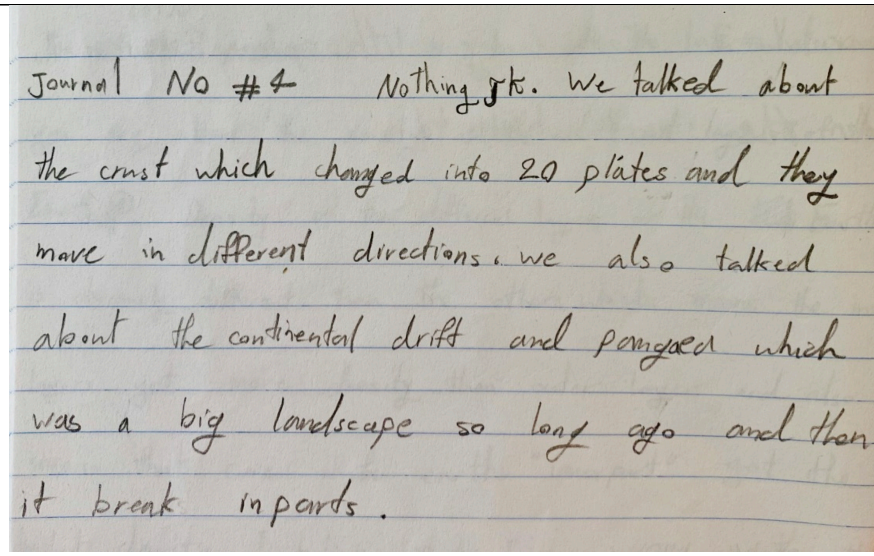
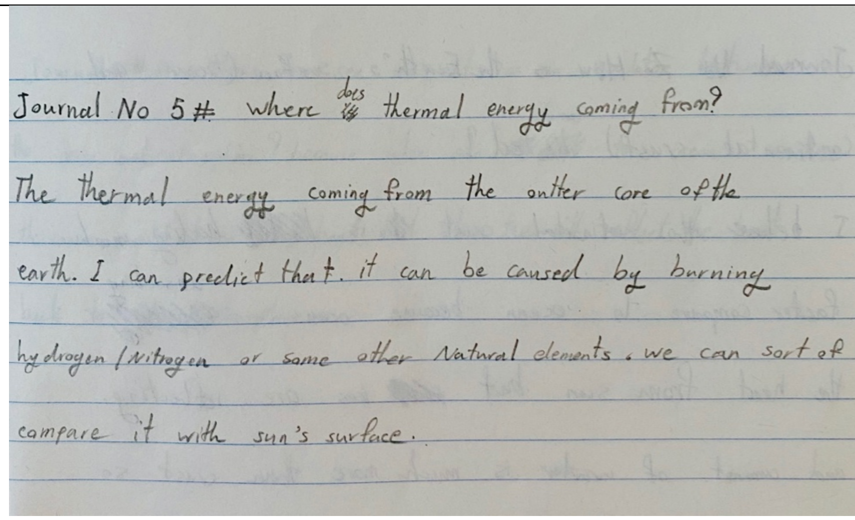
Journal #4: **What do you remember about the continental drift theory?**	 Journal No #4 Nothing jk. We talked about the crust which changed into 20 plates and they mave in different directions. we also talked about the continental drift and pangaed which was a big landscape so long ago and then it break in parts.
Journal #5: **Where does the Earth's thermal energy come from?**	 Journal No 5#. where does thermal energy coming from? The thermal energy coming from the outter core of the earth. I can predict that. it can be caused by burning hydrogen/Nitrogen or some other Natural elements. we can sort of compare it with sun's surface.

Figure 9 Peyz's journals in Earth Science

In reviewing the writing samples from Peyz, I will make a comparison between the CDF of *describing* to delineate how he was able to do language mapping of this function both cognitively and linguistically. As *classifying* fits under the umbrella of *describing*, I will also use examples of *classifying* to show the realization of *describing* in Peyz's writing. The comparison between typical ways to use *describing* in science as suggested by Dalton-Puffer and Peyz's mastery of this function is illustrated in Table 19 below.

Table 19 Examples from Peyz's Journals Using the Function of *Describing*

Ways to Use *Describing* (Dalton-Puffer, 2016, p. 38)	**Peyz's Examples**
To inform about observable features or internal characteristics	*Density of the different layers of the Earth is obviously **different than** the others which means that the **inner layers** got **more density than outer layers and also means that** core of the earth "inner part" got the **highest density**.*
To share some specialist knowledge	*The thermal energy coming from the outer core of the earth. **I can predict** that it can be **caused by** burning hydrogen/nitrogen **or some other** elements.*
To give detail or graphic account of something	*We can sort of **compare it with Sun's surface**.*

The examples above show vividly that Peyz was aware of the functional language of *describing* required of him via the questions. He used the sentence patterns and instrumental words (in bold) specific to *describing* (which means, also means that, more density, highest density) and *classifying* (inner layers, outer layers, different than, some other, compare it with Sun's surface) to satisfy this request. Although some ambiguity resided in his writing, the fact that he understood the cognitive and discursive demands of the questions was clear. A drawing, perhaps representing the Earth, its core and the Earth's layers (a form of pictorial drawing) demonstrated Peyz's multimodal representation of science concepts.

In terms of content knowledge, Peyz's journal entries indicated his understanding of the connection between the movement of the lithospheric plates and the splitting of Pangea. However, he did not seem to be able to understand the role the Earth's thermal energy plays in causing the movement of the lithospheric plates. In fact, after a lesson on the sources of the Earth's thermal energy, Peyz was unsure whether this energy comes from "*outer core of the earth, burning hydrogen/nitrogen or some other natural elements, or can sort of compare it with sun's surface*" (see journal #5). It is apparent that there were conceptual gaps between his everyday knowledge and the science perspective. As a result, the comparison of his writing with the acceptable science explanations in Table 20 (below) did not demonstrate a narrowing gap. Journals #2, and #4 presented closer internalization of perspectives using *description* and *classification* than journal #5 (also exemplifying the functions of *description and classification* but centering on a more theoretical topic). On the other hand, Journal #3, whose content was less complex but demanded a more complex cognitive discursive function, did not display many of the perspectives of school science.

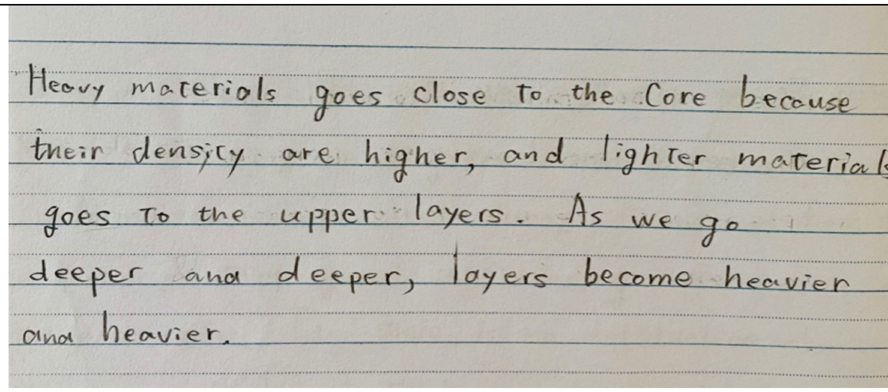
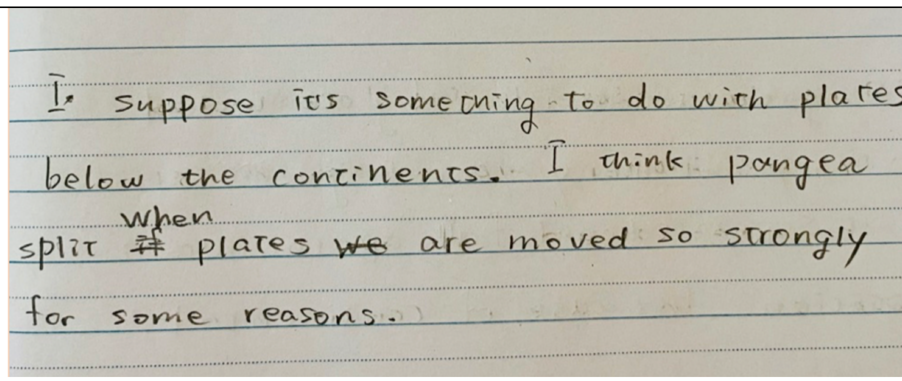
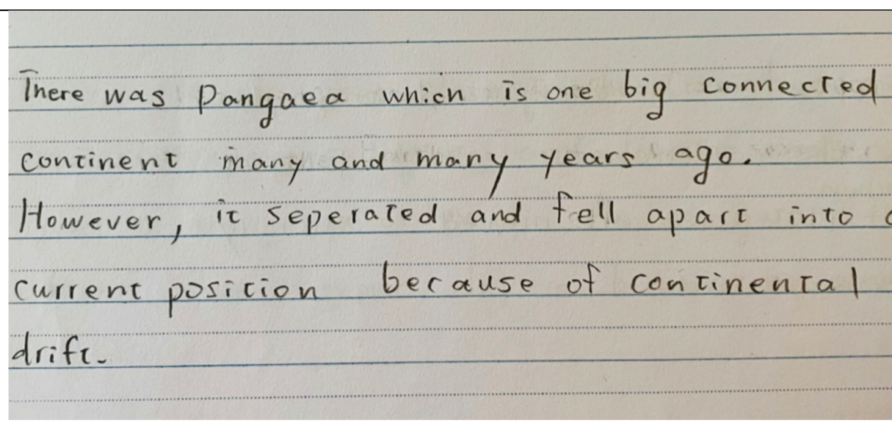
Table 20 The Narrowing Gap in Peyz's Disciplinary Literacy in Earth Science

Journals	Peyz's preliminary and everyday science perspectives	School Science Perspectives
#2	*- The inner layers got more density than the outer layers* *- Core of the earth (inner part) got the highest density*	The Earth's interior layers are ordered by decreasing density from the inner core being the densest to the mantle and the outer core.
#3	*Caused by lithosphere plates moves under the crust*	Pangea split due to the movement of the crustal plates caused by the convection currents.
#4	*-the crust which changed into 20 plates and moved into different directions.* *-the continental drift and Pangea which was a big landscape and break in parts*	The theory of continental drift explains how continents shift position on Earth's surface due to plate tectonics causing Pangea to split.
#5	*-the thermal energy coming from the outer core of the earth.* *-caused by burning hydrogen/nitrogen* *-we can compare it with Sun's surface*	The Earth's thermal energy comes from matter and energy rising and sinking deep within the Earth due to density changes of the Earth's layers.

It is possible that gaps existed in Peyz's understanding of matter and energy flow within the Earth which is inherently a complex, technical content. It is also possible that the gaps resided in the conceptual link between energy flow, temperature change, and density causing the movement of layers, which requires a good grasp of thermal energy and kinetic molecular theory. Either postulation could explain Peyz's faltering perspectives in these few journals. Additionally, Peyz's journals indicated that using language in discipline-specific ways was still in its early stages. However, some useful language features pertaining to the function of *reasoning* were being employed in his writing: "*caused by, which means that, I can predict that, we can compare it with*". All of these clauses can evolve into sentence patterns to enact *knowledge-based reasoning*. Peyz's initial exploration of these clauses suggests growing skills in his disciplinary literacy not only in terms of lexico-grammatical organization and patterning but also in his critical thinking and reasoning abilities mobilized via his language. In terms of his application of language functions and sentence patterns, Peyz's journals entries in earth science show growth in comparison with his writing in the first few classes in genetics. I will now review Rentaro's journals to ascertain if similar or different patterns existed.

Journal Writing for Rentaro in Earth Science

In the figure below, I have copied and pasted pictures from Rentaro's journal book to show his answers to the same four journal questions discussed in the previous section. Rentaro is showing the cognitive/discursive awareness of the scientific registers in responding to *describing* and *explaining* required of him.

Journal #2: **What can you say about the density of the different layers of the Earth?**	 Heavy materials goes close to the Core because their density are higher, and lighter materials goes to the upper layers. As we go deeper and deeper, layers become heavier and heavier.
Journal #3: **What caused Pangea to split?**	 I suppose it's something to do with plates below the continents. I think pangea split when plates ~~we~~ are moved so strongly for some reasons.
Journal #4: **What do you remember about the continental drift theory?**	 There was Pangaea which is one big connected continent many and many years ago. However, it seperated and fell apart into a current position because of continental drift.

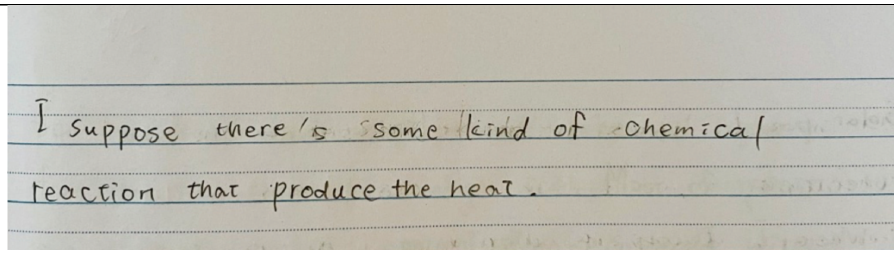
Journal #5: **Where does the Earth's thermal energy come from?**	

Figure 10 Rentaro's journals in Earth Science

In an analysis of cognitive functions mapping out specific sentence patterns, it is useful to use a similar table matching Rentaro's utterances with the typical patterns of *describing* and *classifying* (under the umbrella of *describing*). Here, I will not analyze sentence patterns pertinent to the language function of *explaining* as I have used examples from journals in genetics to do so, even though, Rentaro's explanation to "what caused Pangea to move?" lends itself to such an analysis. For the purposes of analyzing the patterns of language functions of *describing* and *classifying*, the instrumental lexical items are written in bold.

Table 21 Examples from Rentaro's Journals Using the Function of *Describing*

Ways to Use *Describing* (Dalton-Puffer, 2016, p. 38)	**Rentaro's Examples**
To inform about observable features or internal characteristics	*There was Pangea which is **one big connected continent** many and **many years ago**.*
To share some specialist knowledge	***I think** Pangea split when plates are moved so strongly for some reason.*
To give detail or graphic account of something	***Heavy materials** goes closer to the core because their density is higher, and **lighter materials** goes to the upper layers.*

Table 21 displays Rentaro's use of adjectives, such as "one", "big", and "connected" to describe the observable features of Pangea. He also used time as an adjective in writing "many years ago" to further describe Pangea. Rentaro was able to share his knowledge as a specialist when he postulated that "Pangea split when the plates moved". As *classifying* is used as a form of *describing*, there are examples of two classifications or groups that Rentaro used in describing the movement of Earth's layers caused by their relative densities: "*heavy materials goes closer to the core*", and "*lighter materials goes to the upper layer*." Table 21 shows that through exposure to discipline specific language functions within classroom interactions and in text, Rentaro was able to apply them tentatively, yet appropriately.

With regards to content knowledge, Rentaro showed an understanding of the concept of relative density in Journal #2 by stating that "*heavy materials goes close to the core because their density are higher*". In Journals #3 and #4, he stated correctly that the current positioning of the land pieces is due to the movement of crustal plates; however, his writing showed a gap in knowledge: "*Pangea split when plates are moved so strongly for some reason*." The "reason" is that heat causes convection currents which then cause the movement of crustal plates. The role heat or KMT plays in this theory was obscure in Rentaro's writing. In journal #5, he made references to "heat" within the Earth and inferred that a chemical reaction takes place to produce the heat. Rentaro relied on knowledge of heat caused by *"some kind of chemical reaction"* which could be hinting at radioactive decay. As the learners, at this point, had not yet been introduced to the sources of heat, such as radioactive decay and the planet's formation, Rentaro showed critical thinking, indicative of his ability to look for connections to make meaning of newly-introduced concepts, a higher level cognitive ability which Rentaro possessed. He searched for a link to *explain* the source of heat and wrote: denser core material sinking to the centre of the Earth is the source of heat. The comparison of his thought formulation and writing next to the scientific views introduced to learners in grade 10 is offered in Table 22.

Table 22 The Narrowing Gap in Rentaro's Disciplinary Literacy in Earth Science

Journals	Rentaro's preliminary and everyday science perspectives	School Science Perspectives
#2	*- Heavy material goes close to the core because their density are higher* *- Lighter material goes to the upper layer*	The Earth's interior layers are ordered by decreasing density from the inner core being the densest to the mantle and the outer core.
#3	*- Something to do with plates below the continents.* *-When plates are moved so strongly for some reason.*	Plate tectonics caused by the presence of convection currents, moved crustal plates below the continents and split Pangea.
#4	*There was Pangea which is one big connected continent. However, it separated and fell apart into a current position because of continental drift.*	The theory of continental drift explains how continents shift position on Earth's surface due to the movement of the plates known as plate tectonics.

Journals	Rentaro's preliminary and everyday science perspectives	School Science Perspectives
#5	*There is some kind of chemical reaction that produce the heat.*	The Earth's thermal energy comes from matter and energy rising and sinking deep within the Earth due to density changes of the Earth's layers.

Table 22 shows that overall, Rentaro had knowledge of the basic facts in responding to the journal questions. He displayed technical understanding of how low density material moves up (journal #2) and that plate tectonics can explain why Pangea split (journal #3) both of which are in parallel with explanations from "school science perspectives". Yet, beyond the basic facts, Rentaro displayed conceptual gaps and misconceptions between everyday and scientific points of view where he did not link the rising and falling of the Earth's layers due to thermal energy to the cause for convection currents (the explanation for journal #3). He also postulated that a chemical reaction was the source of geothermal energy which demonstrated inconsistencies in his understanding of density changes as they are not chemical reactions, but physical changes, which then demonstrated divergence from the possible explanations in grade 10 science. In terms of lexical and grammatical advances, Rentaro's writing showed a metamorphosis and growth when one revisits his earlier journals in genetics. His writing six months later displayed a good understanding of subordinate clauses: *As we go deeper, layers become heavier; some kind of reaction that produce the heat; Pangea which is one big continent;* as well as his use of conjunctions, such as *however.* It is worth mentioning that, as the transcripts of the episodes illustrated, the majority of classroom scaffolding took place on a lexical level and Rentaro's mastery of other features of the language of science are due to implicit and not explicit instruction of those features. It would be justifiable to say that further scaffolding in sentence patterns and correct use of linguistic choices could help Rentaro make larger leaps in his journey of disciplinary literacy.

Summary of the Journals in Earth Science

Describing as an activity where the writer informs the reader about features and qualities of something, whether observable or internal, took place in these journal entries. Both students attempted to *describe* Pangea, the relative density of the Earth's layers, and the Earth's energy system. They used sentence patterns indicative of the required registers appropriately which showed growth in both cognitive and discursive functions. Moreover, the journals showed that the same conceptual gaps were present in Pezy and Rentaro's writing in earth science. In the explanation for the theory of plate tectonics, both students failed to connect KMT with changes in the density of the earth's inner layers and the emergence of convection currents (journal #3). Furthermore, both students stumbled upon the question about the source of earth's energy (journal #5). I will be able to put these findings in perspective to discuss possible reasons why the causal relationship between "heat", "density" and "the movement of the plates" was absent from journals by both of these motivated and intelligent students. One such reason reveals itself when revisiting the analysis of the whole-class discussion that took place during the "convection cell lab" (episode 3). It can be deduced that the lack of content knowledge on my part which transpired into leaving out the theory of KMT and the concept of density in explaining the movement of water as a convection current was the reason for the present gap in the students' meaning making. Furthermore, in reviewing "where does the Earth's thermal energy come from?" (journal #5), Rentaro and Peyz failed to produce responses in line with the disciplinary perspectives. Although data from the lesson preceding this journal entry was not transcribed, the video recordings showed that I delivered the lesson on geothermal energy as a power-point presentation, lacking dialogic interactions and scaffolding of prior knowledge. Whether my pedagogical strategy, the content of the power-point presentation, or leaving the students out of the discussion of the topic of geothermal energy created the conceptual gap for Peyz and Rentaro will require a more controlled empirical study beyond the scope of the present research.

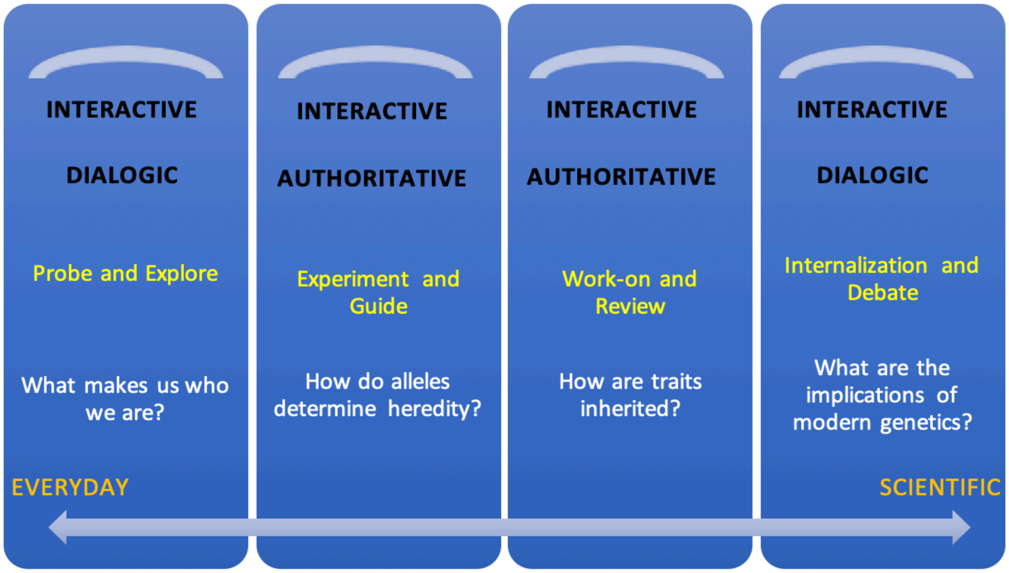
4.5 Summary of Findings

My research is focused on science concept learning and the evolution of students' adoption of the scientific social language in an adapted setting where second language acquisition takes place in tandem with content learning. To answer the question of how I helped ELLs master science literacy, communicative literacies, and knowledge-based critical reasoning skills during a whole-class debate, I reviewed my video-recorded lessons teaching a group of fourteen high school students in grade 10 adapted science over two school terms. I focused on interactions and instructional strategies and the rhythm of the classroom discourse in which conceptually demanding science topics (such as genetic traits and heredity, genetically modified organisms, the Earth's structure, convection currents, and the theory of continental drift) were explored with the students. I selected a few episodes from each of the units on genetics and earth science which respectively demonstrated the following learning sequences progressing from genetic traits to variations via genetic modification of organisms and from the structure of the Earth to the theory of continental drift. All episodes intentionally involved teacher-led lessons as the CA analytical framework was constructed to analyze the speech genre (Bakhtin, 1986) of science classroom interactions mainly by focusing on the teacher's performance (Mortimer & Scott, 2003; Scott et al., 2006). Other aspects of the interactions during the process of guiding the meaning making of conceptual and linguistics items, such as teacher's awareness of the language on the social plane were also examined using the teacher language awareness (TLA) construct (Andrews & Lin, 2017), the language instructional model (5R) (Silva et al., 2012; Weinburgh et al., 2014), the register and genre-based pedagogies of the Genre Egg framework (Lin, 2016) and the construct of CDFs (Dalton-Puffer, 2013; 2016) supporting language development. By drawing from the transcripts of classroom interactions and some of the learners' journal entries, I analyzed the development of the talk of the lesson via gains in language and content learning. Furthermore, I searched for opportunities where language intervention could have explicitly familiarized the students with the academic registers and genres used in science. In the two summary sections below, I hope to bring to light thematic findings that could provide answers to my research questions. In the Discussion chapter following, I will revisit those questions in light of the findings in a comprehensive discussion that draws from the data analysis findings as well as findings from the literature (reviewed in chapter 2) around classroom communicative discourse, student empowerment and competency, and pedagogy as a lens in this journey of curriculum design and as a lens in teacher identity construction.

4.5.1 Findings from the Classroom Interaction Analyses

For each teaching unit, I summarized the analysis of the individual episodes and later created a figure where the episodes could be contrasted with each other according to interactive discourse, teaching purpose, learning objective and content (based on the teaching components prescribed by Mortimer and Scott, 2003). I labeled the figures

“Rhythm of the classroom interaction” for the units of genetics and earth science (Figures 4 and 6 respectively). I will copy the figures here to be able to compare the rhythm of the classroom discourse mobilizing the same teaching purposes across the two units. The teaching purposes moved along the following four stages: *probing and exploring* to *experimenting, guiding and reporting, working on and reviewing* and finally arriving at *internalization*. Before I discuss what the comparison of the two figures revealed, I will explain that, first, discourse was measured across the two dimensions of interactive/noninteractive and dialogic/authoritative (Mortimer & Scott, 2003). Second, the arrow displaying the movement in the content spectrum is double-headed to signify that ELLs’ diverse languages and practices in the everyday domain are not “lesser” or “second-rate”; they are foundational in how new knowledge is understood and internalized. The everyday domain does not need to be left behind; it can be revisited and reshaped. Third, the teaching purposes move through the same stages in both units and create a unifying factor against which the two units can be compared. Fourth and last, the learning sequences indicate the objective of each episode and evolve from “what” questions to “how” and “why” questions. The learning sequence in genetics advanced from “*what makes us who we are*” (the empirical causes) to “*the implications of modern genetics*” (scientific experiments and proof) which was carried out during the final debate episode (see Table 3). In earth science, the learning sequence presented a leap from “*what is the structure of the Earth*” (theoretical descriptions) to “*how the theories studied support the continental drift theory*” (theoretical explanations) (see Table 9). Although, the final debate question, adopted a “yes and no” format instead of exploring the “how” (due to asking the wrong types of questions on my part), the potential to develop a deeper understanding was offered through the teaching sequence. Evidently, the topic of renewable and sustainable Earth’s energy sources formed a lively debate which addressed many “how” and “why” aspects of this complex topic. In other words, the students were scaffolded to begin exploration of topics which presented smaller leaps in learning to eventually engage with topics and questions of great depth and current relevance. Figures 4 and 6 are copied below for a comparison of how these journeys unfolded for each individual teaching unit.



Repeat of Figure 4- "Rhythm of the classroom interaction in teaching Genetics

Repeat of Figure 6- Rhythm of the classroom interaction in teaching Earth Science

First, the figures above illustrate that the **shifts in the communicative approaches** played out differently for the two units. Although both units involved an approach which was highly interactive, the teaching of genetics employed both ends of the dialogic-authoritative dimension whereas teaching earth science became mostly authoritative. In genetics, the students provided ideas which contributed to dialogically shaping the talk of the lesson, such as Jerry offering “special looking” when scaffolding for “traits”, Peyz suggesting “a car dealership” for “exhibited”, and Lisa and Yuki summarizing their understanding of the topic into “*we inherit traits from our parents in our genes*”. Overall, the leaners’ background knowledge was largely aligned with the direction the scientific story was taking in many aspects: in the two variables of genes and the environment influencing our traits, in how inheriting our parents’ DNA defines heredity, and in supporting and refuting the genetic modification of foods and organisms using facts and figures. On the contrary, in earth science, dialogic consideration of the learners’ ideas to form the talk of the lesson was not as powerful; most interactions appeared to follow a unilateral information-giving presentation style or an inquiry in search of a single “correct” answer. Exploring the clay ball presented many avenues for inquiry, such as when Tom referred to “the size”, Peyz suggested the structure of the Sun for comparison or when Gavin proposed “density” which could have initiated the understanding behind mass per volume. However, moving the direction of the social language of the scientific domain to derive at a dense core became the sole focus of the interaction, where I authoritatively turned down the students’ contributions. Similarly, in making observations of the movement of the coloured water in the convection cell apparatus, exploring the students’ understanding of this empirical inquiry was reduced to emphasizing the scientific perspective. Whether the nature of the content or the level of teacher’s content knowledge and language awareness contributed to the disparity in the communicative approach between the two units will be the topic of discussion in the next chapter. Below, I will unpack each of these variables individually and later discuss them in an interlaced context and in interaction with each other.

Second, the **content** of the two units differed by nature; that is the degree of difference between everyday and science views was much larger in earth science than in genetics, as discussed earlier. Hence, on the content spectrum, I accounted for this disparity by labeling the starting place as “everyday” for genetics where much of the science perspectives already resided in students’ common sense and here-and-there experiences, such as understanding of “visible traits”, “family pedigrees”, “genetic diseases”, “GMO’s”, etc. On the other hand, for earth science, I labeled the starting place as “empirical” instead of “everyday” since coming into contact with the structure of the Earth or its composition, is not an everyday experience or knowledge base available to most students. However, the physical phenomena of kinetic molecular behavior or characteristics of thermal energy and density could have possibly resided in the students' toolkit of tangible experiences. For example, students in grade 10 would likely have knowledge of how heat causes particles to vibrate, collide, and move away from each other, occupying more volume for the same mass; hence resulting in reduction in density. I labeled the other end of the content spectrum as "theoretical" to account for the abstract nature of the theories and scientific rules, such as convection currents, essential to make appropriations of new perspectives in earth science possible. Overall, it is reasonable to say that the learning demands were greater in earth science in comparison with genetics due to the nature of the content.

Third, using the component of **teaching purpose** to integrate the findings from the two units can help shed light on the relationship between teaching purpose and discourse oscillating from dialogic to authoritative domain. The data reveals that in both units, the initial probing and exploration of students' ideas was done interactively and dialogically. In both units, the subsequent stage of furthering students' understanding of new ideas and reviewing new learned knowledge was done interactively and authoritatively. I am able to confirm Mortimer and Scott's findings in that a certain communicative teaching cycle resides in moving through the stages of the teaching purposes. Figure 11 below is borrowed from Mortimer and Scott (2003, p. 103), titled "A teaching cycle" to show the stages of the teaching purpose unfolding in a circular manner. Similar to my findings, the initial purpose of exploring students' views was enacted interactively and dialogically while working on students' views was enacted interactively and authoritatively. In Figure 11, the final stage of maintaining the scientific story in Mortimer and Scott's study was also accomplished via interactive and authoritative discourse which diverges from my data in the genetics unit, where maintaining the scientific story and internalization by means of the debate activity was enacted interactively and dialogically. Does a relationship exist in realizing individual teaching purposes successfully through specific discursive interactions? In other words, would it be possible that purpose determines the pattern of interaction? Can the particular teaching purposes once addressed dialogically be equally effectively addressed authoritatively? According to Mortimer and Scott (2003), such a correlation between teaching purpose and the communicative approach is often found; however, they do not suppose that "there should *always* be such a direct relationship between purpose and approach" (p. 103, italic in original). They argue that teaching is unpredictable and thus, approaches can never be precisely mapped out. This could explain why the purpose of “maintaining the scientific story” via the debate episode in genetics was carried out interactively and dialogically whereas in Figure 11, it is depicted to be approached noninteractively and authoritatively.

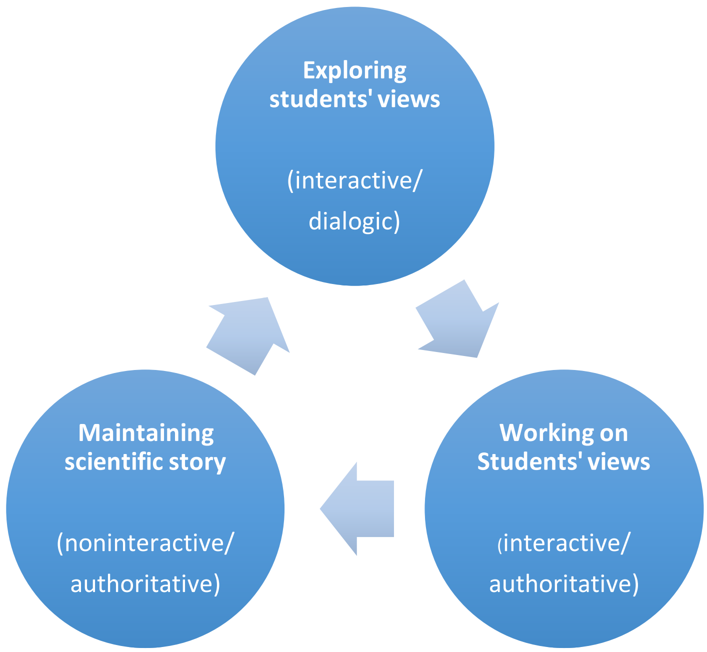


Figure 11 “A teaching cycle”
Scott & Mortimer, 2003, Figure 6.2, p. 103

The topic of TLA is also addressed in this summary. The data showed that the episodes in genetics were coded as displaying TLA in lexical scaffolding and drawing the learners’ attention to paragraph writing with some accommodation for academic language. Purposeful scaffolding took place around the structure of a paragraph, starting with the topic sentence and teaching how to provide evidence to support the claim made in the topic sentence (episode 3 in genetics). Other components of the TLA construct were also present in teaching genetics. I will offer one example (in brackets) for each component as follows: awareness of the language from the learners’ perspectives (the learners created a word map and I used *replace* to scaffold for technical terminology), awareness of the existing gaps (scaffolding for vocabulary such as “inherit” or “exhibit”), preparation of appropriate teaching material (the alien baby experiment and the Animal Pharm documentary), impromptu language interventions (constructing a sample sentence based on the learners’ word map) and ease of access to subject matter knowledge base (moderating the debate). There were also instances where gaps in knowledge, such as the meaning of “alleles”, went unnoticed by me. Similarly, the data showed that ample opportunities to raise the learners’ knowledge of standard and highly frequent disciplinary sentence patterns and academic functions such as *defining, classifying, exemplifying, describing* and *reasoning* were not utilized. Explicit teaching of lexico-grammatical choices in a bottom-up approach according to the Genre Egg framework could have benefited the learners in raising their language awareness. Such language teaching opportunities were also missed when analyzing data in earth science. For example, many components of TLA were largely absent: ease of access to subject matter knowledge base (in investigating the clay balls or exploring the ways to discover the structure of the earth), teaching the language function of *defining* (when exploring mass, volume, density, dense, etc.), asking “how” and “why” questions to scaffold deeper understandings of concepts (in teaching the theory of KMT, thermal energy, and convection currents), and orienting the students with scientific text sentence patterns such as *comparing* and *reasoning* to prepare for the debate (in teaching clauses utilizing *because, since, as a result, however, on the contrary, in comparison*, etc.). Thus, space was available for doing register-based scaffolding and explicit teaching of the lexico-grammatical patterns common-place in science. Highlighting the missed opportunities enables the data to extend itself to making recommendations to CBI teachers, based on the Genre Egg pedagogical approach, which I will discuss in the next chapter. It also raises questions around curriculum design for the training of pre-service CBI teachers: how to design training program curricula that foster maximizing teachers’ PCK and TLA for science teachers in high school who will be responsible to take on all branches of science when less than ideal teaching loads present themselves? And how to accommodate for substantial amounts of pedagogical training within programs when time and financial constraints can be limiting factors?

These questions and the questions raised earlier regarding the interplay of communicative approach, content and purpose cannot be viewed in isolation. In an adapted setting teaching science to language learners, the content, the everyday and the academic language, the teacher, the learner and the curriculum all come into play. Thus, such vital components of the teaching and learning process, such as purpose, discursive interactions, content and TLA need to be juxtaposed against context, classroom culture, issues of identity, teacher training, logistic aspects of exams, time, and space. Furthermore, how does one define success in such an interlayered dynamic? Is success measured by gains in subject matter knowledge, internalization of new perspectives, acquisition of academic vocabulary, increased language awareness such as persuasive writing, formal lab reports, strength of argumentation or all of the above? Could it also be that true measure of success lies in the construction of positive identities and self-confidence for the students? This latter point has not yet been reviewed in the summary of findings. Scanning the data presented in this dissertation, there are references to "feelings of empowerment", "validation of one's perspectives", "gaining legitimacy", and "building an identity of a scientist or a science-knower" which point to overall gains in emotional competency.

For ELLs in content courses, feelings of exclusion, either because they don't share the school's dominant language and/or culture or because the science they did in their home schools looked different or was approached differently, creates emotional uncertainties. If a science activity or a pedagogical approach can communicate with ELLs legitimacy, belonging, agency, and empowerment, I will acknowledge those as building blocks for social and emotional competency and thus achieving success in the lesson. Such instances can be found in the data where integration of the students' ideas and suggestions into the talk of the lesson translated into validation and legitimacy; for example, acceptance of Jerry's proposal of "special looking", using Yuki and Lisa's sample sentence as an example of a scientific answer, or praising Peyz's deep connection comparing the balsa wood with the structure of the Earth. However, the debate episodes offered the strongest indications of internalization of science-knower and expert identities, legitimacy and self-confidence by the students. In negotiating both the controversial issue of GMO's and the global crises around sustainable sources of clean energies, the students spoke with rigour, passion, and courage. They confidently positioned themselves in the argument, "*I think our renewable energy can replace fossil fuels*" or "*The new salmon grows all year. This is very good.*" They also made clear disagreement phrases, "*So this is a very high difference. So we cannot use [clean energies]" or "So, oil is limited right? If you keep using it, you will definitely run out!".* Finally they took on a scientist identity by posing questions to complex issues, "*But, farmers have been interfering with nature for thousands of years. So what if we continue doing the same using technology?"* As a result, in examining the question of which factors contribute to a successful outcome or effective pedagogical strategies, aside from academic gains in terms of content and language, I believe that active and successful participation in a debate lesson can be interpreted as building confidence, social and emotional competencies and new positive identities, which I equate with success. Such internal growth, although difficult to measure with a quiz or an essay, and at times unobservable, needs to occur in conjunction with other forms of learning gains such as the ones I will review next. But before I do so, it is worth mentioning at this point that those episodes in which development of social and emotional competencies and identity construction were evident turned out to be the episodes which were navigated through dialogic discursive discourse.

In a preliminary glance, there is evidence from the analysis of the data and the comparison of Figures 4 and 6 to suggest that in the unit of genetics, the students achieved great success in coming to understand and apply the school science view. The way the students moved from an initial position of knowing some words and making weak connections between genes and the environment as factors determining our traits to a final state of negotiating the pros and cons of genetic engineering showed strong conceptual and language learning gains. A quick glance at earth science, on the other hand, could reveal that the learning sequence of moving the students from making connections between a clay ball and the structure of the Earth to discussing the rigour of the theories and the phenomena in substantiating the theory of continental drift did not equate to success. Do all the successful outcomes correspond to episodes in which I employed dialogic and interactive approaches and the failed outcomes point to authoritative lessons? Clearly, this is not the case. Digging deeper than surface conclusions and the why of each of these tentative outcomes need to be explored and discussed. A review of findings from the students' journals can also strengthen the above emerging thematic patterns, which I will do next.

4.5.2 Findings from Journal Entries Analyses

In the analysis of the journals, I also presented what teaching purposes the journal topics addressed in Table 14. It became apparent that in the earth science unit, the majority of the journal questions revolved around reviewing and articulating knowledge of a key scientific concept introduced to the students in the previous lessons, whereas, in the unit of genetics, activating students' prior knowledge, making connections between old and new knowledge and developing critical thinking and reasoning skills made up the majority of the questions required of the students to reflect upon in their journals. I deduced that it is unlikely that this discrepancy is due to the nature of the two branches of science fostering different types of cognitive skills. Perhaps this discrepancy was more clearly rationalized with a reflection on my PCK in earth science catering to information-giving in authoritative communicative discourses, making fewer cognitive demands of the students and exposing them to fewer disciplinary genres than I did for the unit of genetics. So, how did this transpire in terms of engagement with text, internalization of new knowledge, developing cognitive strategies and acquisition of reasoning skills? How did the students' journal entries display enhanced learning gains?

When reviewing the journals that Peyz and Rentaro had produced in the unit of genetics which was the earlier unit I taught, it was evident that the two boys moved from using sentence fragments, point-form and simple sentences to creating complete sentences with attention to parts of a paragraph. Peyz and Rentaro's journal entries indicated that by the end of episode 5 in genetics, the two students could articulate and somewhat correctly position themselves in a scientific argument with a number of new words to express their scientifically-oriented views about DNA as the basis for biodiversity. For instance, Rentaro referred to the DNA sequence which is the source of biodiversity in "*The parents' DNA pattern which has something same with the child DNA".* Peyz also referenced biodiversity in "*DNA inherited by our parents determines our characteristics.* Furthermore, the final journal showed that everyday science words were replaced with technical academic words (e.g., *inherited, DNA pattern, environment or lifestyle*). Meaningful learning by these two students was displayed where journals offered them the opportunity to position the authoritative discourse of the disciplinary knowledge in relation to their everyday views and consequently internalize this knowledge and make connections between old and new ideas. I attribute the increase in the correct use of field-specific vocabulary and internalization of new knowledge to a myriad of factors such as the rhythm of the adapted instruction where shifts between dialogic and authoritative discourses were in direct response to the needs of the students and to bridging any existing gaps. Aside from the communicative teaching approach, the inquiry-driven lessons, the nature of the content as well as TLA on a lexical level, understanding of key conceptual features from the learners' perspectives, ease of access to subject matter content, and language accommodation moves were contributing factors in finding success. Had teaching in these few episodes included explicit attention to sentence patterns, registers and genres in a bottom-up approach, I speculate that Peyz and Rentaro could have constructed responses to the journal questions even more effectively in conveying their meaning. Here the intention is not to teach the students to follow and replicate only the disciplinary registers, but to teach them the ability to critically compare their journals with those of the standard science text and decipher how meaning is conveyed.

In comparison, a review of Peyz and Rentaro's writings in earth science suggested that the succession of journals did not materialize in deeper engagement with text and/or a deeper grasp of content knowledge. There seemed to be a barrier in linking ideas together and applying new understandings to new situations; for instance, making connections between heat and convection currents due to properties of matter and energy was hindered by the presence of a conceptual gap in understanding density and the kinetic molecular theory causing the movement of crustal plates. It is indeed worthy to explore why the concept of convection currents did not appear in either of the students' journal entries. Was the nature of the subject matter conceptually demanding creating larger learning barriers? Was my PCK inadequate in viewing the key features from the learners' perspectives? Was my TLA insufficient in enacting language accommodations to clarify, define, and describe this concept in order to make connections more clearly? Or was there absence of genuine dialogic discursive interactions which could have assisted the learners with meaning making and knowledge construction in a fundamental and impactful way so that their knowledge could be applied in answering questions which required higher level cognition. To attempt a response, I will revisit the transcript of the episode where convection currents was the topic of a hands-on inquiry during a lab utilizing a convection liquid cell (episode 3). As talk is central to meaning-making and central to learning, it becomes pertinent to review the talk of the lesson in the interactions of that episode. The transcript showed that there was an absence of purposeful and genuine scaffolding in the discursive interaction of the classroom. The interactions transpired in such a way that the theoretical connection between heat, density and the currents was left out of the talk of the lesson. My questions were restrictive and did not utilize the same language the learners had been exposed to during the lesson on KMT. The particles gaining energy, vibrating and colliding were replaced with "*something pushing water to move"* in my questions and feedback (lines 2, 7, and 9). Density and KMT were not tied into the discussion of heat creating a convection current. It is no surprise that both heat and convection currents were missing in linking the movement of the Earth's plates in the journals reviewed. I will discuss the role teachers' questions and lexical-grammatical choices play in creating or closing space for dialogue and meaning-making in the Discussion chapter.

Lastly, the sentence patterns of the CDFs such as *explaining* and *describing*, although imperfect, were evident in the students' writings (Tables 15, 17, 19, and 21). Applying genre-based approaches, such as the Genre Egg framework or the CDF construct has the potential to raise the learners' awareness of discipline-specific lexico-grammar, registers and genres via journal writing. The teacher could evaluate the students' writing by modeling the writing in context and highlighting where improvements and refinements could be made to integrate open-ended writing activities on scientific topics along the course of the development of a science story. Implications of this type of pedagogical approach in CBI will also be discussed in the upcoming chapter.

4.5.3 Thematic Patterns and Conclusions

As talking and thinking are inherently connected, there is good reason to think that deeper, more complex thinking will need to be scaffolded upon probing prior knowledge and preliminary perspectives. In acquiring knowledge, "students bring together two social languages, their newly acquired school science view and an everyday way of talking and thinking" (Mortimer & Scott, 2003; p. 84). Thus, the diverse home languages and home cultural practices that shape the everyday language of ELLs' initial perspectives before they appropriate the technical and the theoretical scientific language are valuable and legitimate. Students will not leave them behind and move away from them, but revisit them, re-think them, and modify them into a social language of science that makes sense to them. Raising the learners' awareness of the differences between the two languages in both perspective and structural aspects is crucial in teaching CBI. Fostering ELLs' sense of confidence, legitimacy and positive identity construction is also crucial in teaching CBI. Tangent to gains in learning outcomes, language learners in senior science need to emotionally and socially prepare themselves for post secondary programs or the workplace. In either case, they need to view themselves as legitimate members of a greater society towards which they can contribute positively. CBI teachers can nurture building confidence and positive identities via sound pedagogical practices, such as conducting dialogic interactions where students' prior knowledge and perspectives are acknowledges and considered, conducting debate lessons in which students can learn criticality and argumentation competency, as well as conducting detailed analysis of language so that the learners become familiar with language patterns at the lexical, grammatical, sentence, functions, text types and eventually context and genre levels.

In the "summary of findings", some thematic patterns emerged: teaching purpose plays a part in determining the communicative discourse of the classroom, everyday content presents smaller learning leaps to the students, TLA can orient the learners with scientific registers and genres necessary in developing the students' critical literacy skills, and pedagogical choices can have confidence and identity building ramifications. Creating classroom conditions that foster flexibility and fluidity of movement along the content spectrum can signal to the students the legitimacy of their views, criticality in thinking expected of them, and the arbitrary privilege bestowed on the disciplinary and dominant practices. In honouring the students' non-scientific knowledge when answering "what makes us who we are" and formulating the response using key words from the students' word map, a sense of empowerment and legitimacy is built in the learning climate, which can support the students in constructing new science identities. Furthermore, inviting the learners to engage in science processes of inquiry dialogically and critically will help them foster confidence in presenting their standpoints and supporting them in light of evidence and knowledge. As reviewed in chapter 2, the role of an "activist" (Kendrick, Early, & Chemjor, 2019) was found to show strong links with confidence building in students and demonstrating competence. I saw the activists taking their first steps in negotiating and debating social issues, practices which my students engaged in while debating the pros and cons of GMO's. Defending their viewpoints, rebutting and repositioning themselves in the argument, the students displayed "argumentative competency" (Kuhn, 1993) via knowledge and the legitimate position of a science-knower. Overall, the data in the genetics unit offered evidence to show that involving the students in the talk of the lesson, promoted academic and social-emotional competence. The less successful outcomes in earth science reinforced this key link between engaging the leaners in the process of knowledge building dialogically and the attainment of academic achievement. Both the transcript of the episodes as well as the journals from earth science indicated existing gaps in key concepts and lower levels of confidence in the negotiation of ideas. Although the final part of the earth science debate about “alternatives energies” instigated the students’ passion and committed them to voicing their viewpoints; overall, dialogicity was lacking in the data. The shift to the authoritative end of the discourse domain in most of the earth science episodes translated into fewer opportunities offered to the learners to build positive identities through engagement and collaboration with others, a strong indicator of social-emotional competence (Cummins & Early, 2011; Varelas et al., 2012).

In summary, I have been able to compare the two units to make sense of the factors that are associated with successful teaching and learning in order to answer my research questions on learning outcomes. The transformation of my identity as a teacher-researcher and later as an analyst will also shed light on this journey of curriculum design, pedagogical decisions, discourse analysis and interpretations of findings. How my awareness of my knowledge changed and how that process impacted my views of self will also be explained. In terms of students’ learning outcomes, I have been able to examine the emergence of language in the course of students’ inquiries during science lessons to understand the ways the students moved from an initial position of everyday and common-sense knowledge to a final state of using the language of the social plane of a high school classroom successfully. A more nuanced and closer analysis of the data in relation with the research questions, and implications for CBI teacher training and curriculum design will be considered in the Discussion chapter.

Chapter 5. Discussion of Findings and Implications

5.1 Revisiting the Research Questions

In this chapter, I will revisit the research questions laid out in the introductory chapters and ask if I have fulfilled what the study aimed to do in attending to the *research inquiry*: how might an inquiry-driven pedagogy unfold in a CBI science class and what can we learn from this process in relation to 1) classroom discourse, 2) ELLs' learning outcomes in terms of proficiency in development of academic literacy and social competency, and 3) teacher language awareness? I aimed for my research to generate data that contributes to answering the following *research questions*:

1. How do classroom interactional discourses in one adapted science classroom influence learning gains and knowledge-based reasoning skills?
2. How does TLA enacting language accommodation strategies impact the rhythm of classroom discourse and students' learning gains?
3. How can a CBI teacher raise the students' awareness of disciplinary language features and conceptual content features, and how does this help the learners develop criticality, confidence and a positive science learner identity?
4. What are the challenges of a teacher-researcher's study in designing and delivering inquiry-driven lessons for English learners in high school adapted science?

It seems logical to me that the first three research questions be elaborated on in the discussion part of this chapter and the last research question be deliberated in the implications section using my research findings. I will organize this final chapter into discussion, implications and final thoughts where I can examine my findings in relation to the gaps identified in the literature.

The surface examination of Figures 4 and 6 revealed some thematic findings as outlined in section 4.5 (Summary of Findings). However, boxing the data into figures and tables runs the risk of overlooking the nuances of classroom interactions, situated in context and bound by the social discourses of the classroom. Therefore, I looked further and coded my analysis of the data based on the interconnectedness of the emerging themes as all four components of the framework (teaching purpose, content, communicative approach, and patterns of interaction) articulated with one another in interpreting the way each teaching episode played out. Furthermore, how each of the components of the framework interacted with my TLA in mobilizing language teaching strategies, enacted through lexical scaffolding and genre-based pedagogies, needed to be investigated for the findings to be meaningful in an adapted setting. Lastly, my own understanding of where my strengths and weaknesses lied in relation to PCK and TLA, ought to come into the interpretation of my findings as these teacher knowledge bases impact the classroom climate where students' feelings of success, empowerment, and the ability to reason critically and build competency are fostered. The following themes were found and will be elaborated on in this chapter with the goal to answer my research questions and make recommendations for CBI education programs:

1. My data revealed distinctly different discursive interactions in teaching the two units of genetics and earth science.
2. Both teaching purpose and subject matter content seemed to influence the rhythm of the discourse.
3. Dialogic interactions motivated student participation and reasoning.
4. TLA impacted the rhythm of the classroom discourse.
5. TLA impacted how I employed genre-based pedagogical strategies, asked the types of questions that foster scaffolding of perspectives and negotiation of diverse viewpoints, and raised the language awareness of the students.
6. Language instruction did not impede science content leaning; it facilitated content learning in parallel.
7. Students' knowledge-based reasoning skills were a key factor in making a debate successful and creating building blocks for developing social and emotional competencies.
8. Teacher/researcher/analyst views of self and views of teacher knowledge base influenced the study design and the interpretation of the findings.
9. Questions around interdisciplinary collaboration, team-planning and team-teaching were raised.

The above findings are in an interactive dynamic with each other within the time and space provided in the classroom; therefore, to view them independently with the goal to provide a comprehensive answer to each research question, will not be fruitful. I will attempt to make sense of them in the integrated dynamic of the pedagogical variables within my research questions. I present Table 23 to illustrate how I plan to organize this chapter while addressing each research question using my findings. In the Table below, I have matched my findings from the data analysis chapter with the research questions in an interlaced and overlapping manner where more than one finding can address a part or all of one research question, and the same finding can satisfy a response to more than one question. The first two questions - examining discourse, pedagogy and TLA - will be discerned in the Discussion part of this chapter and the last two questions, unfolding issues of identity, empowerment, and educational implications will be explored in the Implications section. I will revisit the gaps in the literature, delineated in chapter 2, and will offer some concluding thoughts to reconnect with topics on critical literacy and issues of inequity mentioned in the literature review.

Table 23 Research Questions and the Corresponding Findings

Research Questions	**Findings**
1. How do classroom interactional discourses influence gains in content and reasoning skills?	- My data revealed distinctly different discursive interactions in teaching the two units of genetics and earth science. - Both teaching purpose and subject matter content seemed to influence the rhythm of the discourse. - Dialogic interactions motivated student participation and reasoning.
2. How does TLA impact the rhythm of classroom discourse and learning gains?	- TLA impacted the rhythm of the classroom discourse. - TLA impacted how genre-based pedagogical strategies were employed with the capacity to raise the language awareness of the students. - Language instruction did not impede science content leaning; it facilitated content learning.
3. How does raising the students' language awareness help them develop positive science learner identities?	- TLA impacted how genre-based pedagogical strategies were employed with the capacity to raise the language awareness of the students. - Students' knowledge-based reasoning skills were a key factor in making a debate successful and creating building blocks for fostering social competencies.
4. What are the challenges of designing and delivering lessons for adapted science in high school?	- Teacher/researcher/analyst views of self and views of teacher knowledge base influenced the study design and interpretations. - Questions around interdisciplinary collaboration, team-planning and team-teaching became evident to me in reflecting on my data and analysis.

5.2. Discussion: The Rhythm of Science Classroom Discourse

5.2.1. A Prelude: Findings in Conformity with the Literature

In this section, I will review my findings for areas of conformity with the seminal works from Mortimer and Scott (2003) and Scott et al. (2006). There are four themes that have emerged from my data analysis which have been established by Mortimer, Scott and Aguiar. Highlighting shared themes and discussing them in the context of my data will help create a wider application for my findings. Additionally, these themes collectively help provide a comprehensive answer to my first research question: **how do classroom interactional discourses in one adapted science classroom influence learning gains and knowledge-based reasoning skills?** I will first unpack the shared themes (below) and then illustrate how together they help answer my first research question. I will discuss each theme in a separate subsection.

1. *Patterns of interaction* are linked to classroom discourse
2. *Teaching purpose* determines classroom discourse
3. *Content* shapes classroom discourse
4. *Dialogic interactions* motivate student participation and learning gains

5.2.2 Patterns of Interaction are Linked to Classroom Discourse

First, two patterns of interaction were identified in the literature: the I-R-E pattern or triadic and the I-R-F-R-F pattern or chain. The works of Mortimer and Scott in 2003 and Scott et al. in 2006 delineated a relationship between the two patterns of interaction and the communicative approaches of dialogic and authoritative discourses. My findings also allude to a link between these two types of patterns of interaction and the two dimensions of the dialogic and authoritative approaches; in a way that dialogic approaches are played out by I-R-F-R-F chains and authoritative approaches employ mainly I-R-E triads. In the summary tables I constructed after the analysis of each teaching episode, I indicated the communicative approach and patterns of interaction separately. In every instance, the I-R-F-R-F chains corresponded with the dialogic approaches and the I-R-E triads matched the authoritative communicative approaches.

This finding is highlighted by the developers of the CA framework as the "how" of materializing enacting an approach; that is dialogicity in a classroom interaction is materialized when the teacher offers feedback to inquire further about students' perspectives instead of evaluating students' responses positively or negatively. In this case, the consistent feedback-giving creates an I-R-F-R-F chain. On the other hand, authoritative discourses unravel in short chains of *initiation, response*, and *evaluation* where there is room for only the scientific point of view to be explored and considered. It is noteworthy to add that the *interactive/noninteractive* aspects of the communicative approach are also tied strongly but not exclusively to the patterns of interaction where the I-R-F-R-F pattern of interaction invites and extends the communicative discourse to be *interactive* and the short triads of the I-R-E pattern closes the avenues of interaction and results in *noninteractive* exchanges. I have not devoted much discussion to the *interactive/noninteractive* aspect of the communicative approach as the episodes I examined and analyzed were all interactive (with the exception of the second part of the first earth science episode on the topic of the early discoveries about the Earth's structure, where I read from my notes to the students in a lecture). As my research focuses on discourse analysis of classroom interactions between teacher and students, I searched for data with the potential to reveal answers to my research questions nested in the interactive communicative discourses of the classroom.

5.2.3 Teaching Purpose Determines Classroom Discourse

Second, a theme that I have briefly discussed in the previous chapter, and one which has been examined by Mortimer and Scott in length is the component of teaching purpose determining the discourse of classroom interaction. Mortimer and Scott constructed a "teaching cycle" (Figure 11 in the previous chapter) in which the teaching purpose is progressing through a cycle of initial exploration of ideas to guiding students to work with the scientific meanings to maintaining the development of the scientific story. This cycle of teaching purposes adheres to a specific communicative discourse in each stage: exploration of student views adopted a dialogic approach, working on scientific meaning making took on an authoritative approach, and maintaining the science story also adhered to the authoritative approach. Mortimer and Scott (2003, p. 103) state that there is no stringency in this kind of coupling of teaching purpose and communicative discourse:

> The combinations of teaching purpose and communicative approach that we see here make sense to us… We are not, however, arguing that there should *always* be such a direct relationship between purpose and approach. Teaching never works out in that precise, predictable kind of way in practice. For example, it would be perfectly possible to act to maintain the scientific story through an interactive/authoritative approach, with the teacher rehearsing the progress achieved through interactions with students, rather than by making an authoritative presentation. (Mortimer & Scott, 2003, p. 103, italics in original)

The point conveyed above is precisely what I found in my data as discussed briefly in the summary of findings. In the successful episodes of genetics and earth science, the initial exploration of students' ideas was done dialogically, and the reviewing of the new meaning making was done authoritatively in line with what the scholars found in their research. However, guiding the learners to experiment with the newly introduced concepts and maintaining the development of the science story was also done dialogically in the earth science unit and resulted in a successful outcome where Peyz was able to make a connection between balsa wood sinking into syrup after syrup was heated as a simulation of crustal plates rising and sinking to demonstrate the theory of plate tectonics. This same teaching purpose was carried out authoritatively during the alien baby experiment where I did not notice the gaps -the students' disengagement with the experiment results- and instead presented to them the scientific perspective before unpacking the "why" of the results which could have translated into: *genotypic information (known as alleles) carry the genetic code (or the DNA sequence) and determine the traits of the alien babies.* The authoritative approach created a less successful lesson where, in revisiting the transcript, I noticed many of the students' questions and inquiries unanswered- a real opportunity for dialogic engagement was missed. To reiterate, I have established that the different ends of the dialogic-authoritative domain seem to operate best to achieve particular teaching purposes; however, this relationship is not restrictive and fixed: the same teaching purpose might be just as effectively addressed through the alternative communicative approach based on the way the scientific point of view is introduced in the context of the classroom or how space is made available for raising the language awareness of the learners through scaffolding and modeling.

5.2.4 Content Shapes Classroom Discourse

A third point that I will briefly explain is that my data revealed a strong link between *content* and the way discourse shifted across the dialogic-authoritative dimension conforming Mortimer and Scott's claims that different forms of discourse emerge due to various content. There is a myriad of examples from the two teaching units were data revealed that when content was embedded in students' everyday experiences, students' initial and tentative views were aligned with the disciplinary perspectives, and consequently the learning barriers were lowered. For instance, in brainstorming "what makes us who we are", the students created a word map which included the following words: *cells, biology, chromosomes, parents, workout,* and *food.* The prescribed learning outcomes required that the learners work with the following terminology in addressing the above question: *traits, genes, DNA,* and *environment*. Such close proximity between what the learners already knew and what was expected of them assisted them in formulating their thoughts in cohesive and accurate sentences by the end of one class period: *We inherit traits from our parents in our genes.* The mastery of the genre of scientific writing and definition-giving did not present challenges to the learners when the content was already available to them. The rhythm of the classroom discussion adopted a dialogic discourse where the students' perspectives were invited and integrated into the talk of the lesson as there did not need to be much filtering and sorting. A genuine dialogic approach became the natural pattern in the interaction: probing for ideas, approving of the ideas, integrating the ideas and using them to advance the scientific story in the talk of the lesson. In contrast, in earth science, the content, less firmly rooted in the everyday science language of the students, was aimed to build a theoretical model, generally applied in explaining a wide range of physical and chemical phenomena related to the Earth's structure and composition, such as plate tectonics, convection currents and the continental drift theory. The nature of the content led to a passage that was faced with significant learning barriers due to content unfamiliarity creating larger learning demands. The transcripts of the episodes from teaching earth science exhibited largely authoritative discourses dominating the talk of the lesson. Thereby, my data confirms the findings from Mortimer and Scott (2003) and Scott et al. (2006) that the content of the lesson sets the tone for the communicative approach within the interactive exchanges aimed at advancing the science story.

To avoid making a surface observation in concluding that only subject matter that lends itself to students' everyday life experiences can invite dialogic discourse, I will draw two examples of dialogic interaction from the unit of earth science in which the learners did not have everyday prior knowledge in line with the rules of the scientific perspective. My first example is from episode 1 where the initial probing of prior knowledge was done by using two clay balls of equal size and varying densities to arrive at the possibility of the Earth being structured in layers with a dense core. The learners used their tactile senses of everyday tangible experiences to decipher differences of weight for a fixed size. The concept of "density" emerged in the interactive exchanges and later paved the way for the idea of a core with distinctive characteristics. In these exchanges, the communicative approach was dialogic, where I used the learners' perspectives to establish ideas related to one another in telling the story: from the idea of "*inside*" to the presence of a "*core*" and potential adjective to describe the core, and to eventually arrive at *dense* and *density*. In this approach, the dialogic dimension dominated the discourse moving the content from empirical and experiential to a theoretical description of unobservable characteristics such as density. Interestingly, the example I'm using as a model for dialogic discourse lacked high levels of interanimation and strayed from key strategic moves, for example defining density, mass and volume in the early stages; equating size with volume and weight with mass to bridge old and new knowledge; teaching the language functions of comparing and describing; and introducing the formula for density as mass divided by volume. The point is that although skillful scaffoldings to help the leaners make the necessary linguistic and conceptual connections were absent in many parts, the dominant discursive interaction was dialogic where learners' perspectives were considered and tied into the social language of the scientific lesson despite the content being technical and theoretical.

The argument I hope to make is that pedagogical strategies in deconstructing science concepts into accessible everyday experiences of science where learners can apply their existing knowledge-base (such as investigating clay balls) in understanding new perspectives (such as discovering the structure of the Earth) is an effective way to invite dialogicity when there is a dearth of everyday and familiar experiences with the content. I make the case that the theoretical and non-everyday nature of the content of earth science did not necessitate an authoritative approach. In addressing the purpose of exploring and probing students' background knowledge, I was able to bridge between the learners' experiences of weight and size and the cognitively demanding conceptual understanding of the Earth's dense core. The ability to introduce the topic of the structure of the Earth (rooted in a non-everyday domain) in a way that drew from students' lived experiences suggests that dialogicity is not reserved for lower cognitive tasks and contents of smaller learning barriers.

5.2.5 Dialogic Discourse Enhancing Learning Gains

Why so much emphasis on dialogic processes? Why go the extra mile to include others' perspectives when eventually we arrive at a single perspective, the disciplinary perspective? Are dialogic discourses superior to authoritative ones when it comes to teaching science? Mortimer and Scott (2003) and Scott et al. (2006) expertly bring to light that there are connections between ways of thinking and talking in the language of science and that dialogic engagement, universally rare within the context of high school science, is motivating for students since it draws the students into the inquiry or the investigation, "legitimizing their expression of whatever ways of talking and thinking they possess" (2006, p. 622). In this manner, meaning making becomes a dialogic process of engagement through the connection between thinking and talking. In an adapted setting, thinking and most significantly talking in the social language of school science presents many challenges to the learners, and this is why it is even more crucial to ensure that the discourse of the classroom includes as many dialogic engagements as naturally occurring and skillfully planned. The presence of this kind of discourse motivating the process of meaning making was evident in the transcript from the first episode in genetics where through genuine scaffolding in a dialogic interaction, Jerry's idea of "traits" as "special looking" either as a definition or an example permeated the talk of the lesson and assisted the learners to arrive at the scientific perspective of traits as "unique physical characteristics". Jerry had conceptually understood the statement, "*we are similar in some ways to our parents",* and was exploring with the language to align his thinking with the language of school science. Similarly, in episode 2 of earth science, when probing for deeper connections in how the heated syrup and balsa wood could relate to the Earth's layers and eventually the theory of plate tectonics, Peyz was able to navigate his thinking through his talking: "*because they're losing density and then they're coming on top of each other and forcing another one to go down".* In this example meaning making as a dialogic process of consideration of others' views can be vividly depicted. Thus, in an adapted setting, when students engage in the dialogic process of exploring and working on ideas with a high level of interanimation and are asked to express their thinking through talking in small groups or with the classroom teacher, meaning making within the context of the scientific point of view can take place.

Furthermore, exposing the learners to field-specific vocabulary in science is a big part of teaching in the adapted setting and it cannot be accomplished more effectively and with higher levels of interanimation than when new science words are offered by the students themselves. In the second part of episode 1 of genetics, Lisa and Yuki wrote "*We inherit traits from our parents in our genes."* The word "inherit" had not been introduced yet and I considered it my responsibility to present it to the students where the style would be information-giving, less participative and most certainly, less learner-centered. By weaving the concept of "inherit" into their sentence, Lisa and Yuki helped open-up the problem of how genetic information is passed to offspring- an important topic of future lessons. There are many other instances from the data which I highlighted that the consideration of the students' suggestions shaped the talk of the lesson. The benefits of dialogic interactions where students become active in developing the social language of the school science resides in giving the learners empowerment, confidence and a voice as legitimate science users instead of reducing their participation to listening, receiving and regurgitation. I believe that the consideration of student perspectives in these early dialogic interactions was a strong factor in influencing their subsequent classroom participation, such as the debate lessons. These early stage validations and implementations of students' knowledge afforded them confidence in expressing more of their diverse knowledge on classroom topics certain that they are valued and acknowledged as science-knowers and experts. The debate is an example where the learners display the development of social competency in confidently expressing their views in agreement or in contrast with the established views and with each other. An examination of how shifts in discourse motivated reasoning and competency development during the debate will take place in the next section.

5.2.6 The Rhythm of Discourse Facilitating Reasoning and Debate

In the literature review of ADI, it was foregrounded that the discourse of classroom interactions in which language and content intertwine becomes the space for teaching the pragmatics and the semantics of science debate and argumentation

(Duschl & Osborne, 2002; Khine, 2012; Osborne, 2001; Mortimer & Scott, 2003). The transcript from the debate episodes in the unit of genetics showed a great level of achievement in the practices of argumentation. The students engaged in debating the controversy of GMO's with confidence, knowledge, perspective-taking and the ability to make deeper connections in a genuine dialogue and exchange of ideas. On the contrary, the earth science debate episode exemplified that scientific ideas were not fully internalized by the learners as they showed difficulty in applying them to make connections between theories or to expand on what causes natural phenomena when explaining theories in support of the continental drift. What accounted for success in the genetics debate and what elements were absent in making the debate in earth science successful? To answer this question, I will not merely focus on the discursive interactions during the debates but examine the ways the students moved from an initial position of everyday and common-sense knowledge during the earlier episodes to a final state of using the language of the social plane of high school science to negotiate viewpoints using the practices of argumentation. Additionally, I will briefly highlight where discourse offered space for the development of social competency which goes hand-in-hand with consideration of others' views in dialogic interactions. An in-depth consideration of the connection between discourse and students' development of competency will take place later on in this chapter.

When tracing the course of the lessons in genetics that build up to the debate episode, Figure 4 summarizing the rhythm of the classroom discourses during the genetic unit showed that when opening up the problem, exploring the students' everyday views and guiding the learners during the process of meaning-making, the discourse adopted both dialogic and authoritative approaches. I attribute the success of the debate to the presence of this rhythm: dialogicity and authoritativeness intertwined in a highly dynamic process. As Mortimer & Scott (2003) explain, dialogic interactions serve to model intellectual engagement with scientific content that it is legitimate for the learners to question, reason and discuss rather than merely accept; in other words, it is empowering for the students to "talk science". The notion that dialogic discursive interactions could have fostered the students' abilities to use argument more effectively was introduced in the literature review chapter by drawing from the works of Duschl and Osborne (2002) and Callahan et al (2019). Here, I support the claims made by Duschl and Osborne that argumentation must be dialogic as it "requires the opportunity to consider plural theoretical accounts and the opportunity to construct and evaluate arguments relating ideas and their evidence" (p. 52). My findings in teaching genetics showed that the consideration of plural accounts permitted dialogic discourse as they modeled to the students the practices of exchanges of ideas, reasoning, and evaluating, which collectively contributed to higher-order thinking. However, my data showed that there were many authoritative interventions in the course of the teaching in genetics leading to the debate.

With the use of the documentary, "The Animal Pharm", students' internet research and my information sheets in preparation of their parts for the debate, the disciplinary perspectives of the scientific story were added to the students' toolkit. Therefore, authoritative discourses disclosing facts, findings, experiments and long-term impacts of genetic modification were just as much integral to the learning progression that resulted in a successful debate where the students were able to construct knowledge by comparing their own beliefs with the school science views. My data shows that it could not have been sufficient to engage students in dialogue about their everyday views of genes, genetic modification, genetic engineering of foods, and ethical issues surrounding them; there needed to be interventions, equally instrumental in introducing the science perspective. In other words, the success of the debate negotiating the pros and cons of GMO's could not have occurred naturally had the disciplinary views and the scientific social language been ignored. This tandem communicative approach of teaching the scientific perspectives, theories and phenomena while validating the learners' own ideas, pools of knowledge and everyday conceptions of science fostered students' abilities to ask questions, evaluate and reason; in other words, to show scientific citizenship. The connection between validating students' ideas dialogically and the promotion of their sense of "scientific citizenship" was articulated in the literature review (Garzón-Díaz, 2021). The idea is to expand ELLs' repertoires of knowledge and skills without constructing a disciplinary hierarchy of literacies, and without denigrating students' own familiar home and community languages and resources (García & Li, 2014). This holistic approach paved the way for the debate to take place where argumentation was supported by the learners' ability to draw from the scientific perspectives and their competencies in socially legitimizing their roles as science-knowers. Reasoning in the language of science requires access to the knowledge and this could not be warranted if the scientific principles, theories, and perspectives were not taught. This is where the expert teacher has to navigate in the tension that exists between developing the dialogic approach of encouraging students to make their views explicit on the one hand, and focusing more authoritatively on the structured scientific view of the world, on the other.

In a similar vein, the absence of success in the earth science debate episode could be linked to the fact that the scientific story of the Earth's structure, its theories and phenomena had not been fully mastered by the learners; that is, students' reasoning lacked knowledge of the scientific concepts. The data showed that classroom interactions were placed predominantly on the authoritative end of the dialogic-authoritative dimension where much of class time was devoted to delivery of information and the presentation of the structured views in science. This should have resulted in knowledge-based reasoning during the debate. However, a closer examination of the analysis of the episodes during teaching the convection currents, plate tectonics and the theory of continental drift, showed that a dearth of content knowledge and a lack of TLA in "provid[ing] appropriate language-related mediation" and "help[ing] leaners notice key features in language" (Andrews & Lin, 2017, p.61) contributed to disengagement and inability to build deep connections between concepts. The episodes showed that I mainly focused the attention on the scientific point of view, ignoring learners' gaps in knowledge and misconceptions. I did not identify where linguistic structures could realize structural patterns for a top-down genre-based analysis to achieve a communicative purpose in teaching text-in-context. Furthermore, the episode of the convection currents lab displayed weakness in the rigor of the questions I posed where the field-specific lexical items in KMT (i.e., the vibration and movement of particles away from each other) were replaced with "something pushing warm water to move up" in the absence of an explanation of how density relates to this scientific phenomenon. To expect the students to make connections in terms of theories supporting the continental drift, it was no surprise that ideas were formed hesitantly and loosely. Thereby, the debate showed that the types of questions I asked when demonstrating the convection current experiment as well as the questions I asked to help build connections in cause/effect and explanation of phenomena fell short of rigorous, relevant and intelligible knowledge upon which the learners could build more sophisticated layers. Thus, the data points to the importance of content knowledge and pedagogical content knowledge which encompasses ZPD discussed in the literature review, highlighting the importance of identification of what the learners already know and utilizing this knowledge to build more knowledge and guide them to independent problem solving.

In summary, my data showed support for established findings in research discussed earlier which argue for dialogic discourse as fundamental to scientific reasoning where legitimization of students' views need to be transparent in discourse. My data also shows that dialogic approaches in isolation are not sufficient; the orthodoxy of the disciplinary perspectives forms the backbone of argumentation from which the learners can draw, compare, learn, modify and critique. A successful debate exemplifies the fruit of expert pedagogical strategies and TLA of many teaching components where the two forms of discourse as a tensioned and dialectic dimension shift "such that one form of discourse gives rise to the other in supporting meaningful learning" (Scott et al., 2006, p. 628) to empower students to take ownership of the scientific point of view.

5.2.7 Revisiting the First Research Question

The first research question asked: How do classroom interactional discourses in one adapted science classroom influence learning gains and knowledge-based reasoning skills? Over the progression of the unit of genetics I witnessed increasingly greater levels of participation and voluntary sharing of ideas. The students became more autonomous and agentive in their learning processes as their repertoire of knowledge grew and they felt more confident providing responses based on internalized views of school science. Such evidence was found in the transcripts provided for the debates that took place in the final episodes in genetics negotiating the pros and cons of GMO's and in earth science debating whether renewable energies could replace fossil fuels. The students were able to position themselves in the scientific debate, construct explanations and evaluations, and contradict the opposing views - characteristics of a scientific debate. They used evidence-based and knowledge-based reasoning to navigate the inquiry in an argument-driven approach. This outcome could not have been achieved, had the talk of the social plane been authoritative in its discourse modeling to the learners unilateral thinking. As Mortimer and Scott (2003, p. 116) suggest:

> Even more fundamentally, if the talk of the social plane is restricted to the authoritative classes of communicative approach, then those ways of *talking* about science are likely to be internalized as the principle ways of *thinking* about science. If we want to encourage students to engage in

> explorative thinking about scientific matters, taking into account different points of view and trying to make links between them, then this mode of *thinking* needs to be modelled in the *talk* of the social plane.

The above theme resonates with my first research question examining the link between dialogic teaching and students' criticality and reasoning. From my data, three of my findings, in parallel with themes in the literature, assembled a response to this research question. The findings are repeated here:

- My data revealed distinctly different discursive interactions in teaching the two units of genetics and earth science.
- Both teaching purpose and subject matter content seemed to influence the rhythm of the discourse.
- Dialogic interactions increased student participation and learning gains.

The discussion of the above findings thus far illustrated that when content presents smaller learning barriers and teaching purpose aims to explore learners' views with high levels of interanimation, discourse tends to adopt a dialogic approach. Within this approach, students feel motivated and validated to volunteer their views, which in turn benefits them by attributing to them legitimacy and competency. When students' prior experience is acknowledged and when they become active members of the classroom science community, they internalize this identity and gradually play the role of a scientist in questioning, investigating and evaluating answers in all aspects of life. They will practice critical thinking skills and learn to demand that their views are heard. All of my examples demonstrating dialogicity in classroom discourse pointed to high levels of student participation, tied with greater learning gains and advancement in acquisition of knowledge and skills - interlayered and reinforcing each other.

5.3 Discussion: Contributing to the Discourse of Adapted Science within CBI

So far, the conclusion reached suggests that discursive dialogic interactions benefit students in increasing levels of participation, learning gains, and competency development. What I ask now is: how are dialogic interactions fostered within CBI in the context of teaching language in high school science? This is in response to my second research question: **How does TLA enacting language accommodation strategies impact the rhythm of classroom discourse and students' learning gains?**

In this section, I will attend to the discussion of the thematic findings outlined in the introduction of this chapter- those which have not been discussed by Scott, Mortimer and Aguiar in their research with mainstream high school science students. These themes will engage the analytical variables I used to modify the CA framework in order to utilize it in a CBI setting. These variables are the TLA construct and language accommodations by means of genre-based pedagogies and lexical-scaffolding models which have collectively impacted the rhythm of the classroom discourse in the dialogic-authoritative dimension. Figure 12, below, visually represents such an interaction where all three pedagogical variables are interconnected. The degree of commitment to the various aspects of TLA via applications of language accommodation can impact the communicative approach in the social discourse of the classroom shifting between dialogic and authoritative dimensions. Strictly speaking, this interaction translates into a mutual relationship: 1) attending to and teaching the discipline-specific registers and genres indicate consideration of the key features and gaps in the language from the learners' perspectives, which realizes a dialogic discourse (TLA impacting discourse), and 2) the rhythm of the discourse can open or close the spaces available for dialogue and thus can bring to light learners' needs for language-specific scaffolding with attention to form and function (discourse mobilizing TLA). Furthermore, the arrow between TLA and language accommodation is also double-headed to indicate that there is a relationship where the two variables can mutually enact and impact each other: the higher the level of TLA in all aspects of the language of the discourse, the more likely language accommodation will take place frequently and meaningfully. In a similar vein, the accommodation of meaningful language interventions indicates a high level of TLA in many aspects. Hence, another mutual relationship exists. Figure 12 demonstrates this interconnected space by displaying the relationship between the three variables.

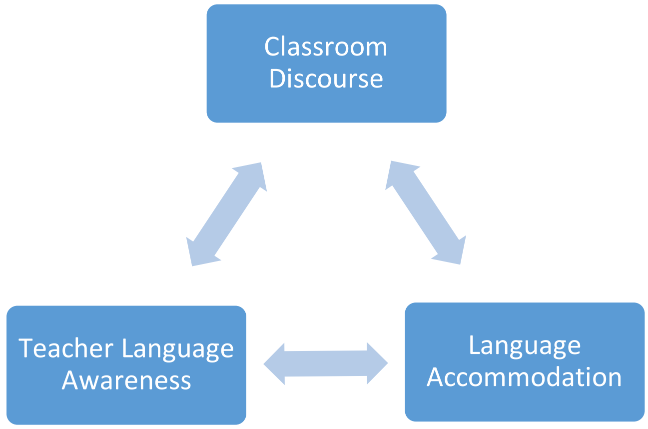


Figure 12 The interplay between TLA, language accommodation moves and interactional discourse

First, I will delve into a discussion of how TLA impacts the discourse of adapted science classroom, and then I will examine the interaction between these two variables (TLA and classroom discourse) in relation with language accommodation strategies to address the needs of ELLs. This addresses my second research question: **How does TLA enacting language accommodation strategies impact the rhythm of classroom discourse and students' learning gains?** In Table 23, I indicated that the analysis of my data elucidated to a response to this question: 1) TLA impacted the rhythm of classroom discourse and impacted how genre-based pedagogical strategies were employed with the capacity to raise the language awareness of the students, and 2) language accommodation did not impede science content learning, it facilitated it in parallel. These themes, grounded in data, will be discussed in the next section to explicate that TLA can, in fact, impact the rhythm of discourse for greater learning gains. These gains are in the form of conceptual, linguistic and student empowerment. Moreover, the skillful facilitation of language-based instructional strategies does not hinder content learning; it supports it. The discussion follows next.

5.3.1 TLA and the Communicative Approach

First, I will examine how TLA influences the rhythm of discourse and how this interaction impacts content and language gains. As an introduction to this section, I will allude to the expertise needed, on the part of the teacher, to fluently engage in dialogic interactions with students, a "highly skilled performance, indicative of a high level of insight and expertise" (Scott et al., 2006, p.624). This kind of insight and expertise equates with the construct of TLA (Andrews, 2007) as introduced in the literature review chapter and used as an analytical tool in my data analysis. Thereby, I will examine the interplay between TLA and the rhythm of the communicative approach to shed light on the intricacies of the knowledge base of the teachers in order to materialize content and language objectives in the most effective interactional discourse. This kind of teaching does not simply rely on content knowledge alone, there are pedagogical skills in the "know-how" of being able to draw upon students' prior knowledge to engage them dialogically, as well as exposing the learners to the disciplinary views authoritatively. I used the TLA constructs put forward by Andrews and Lin (2017) in analyzing my data based on the many components of TLA (Table 1) and will now review the analysis of those episodes to delineate the relationship between TLA and the communicative discourses which played out. To make the discussion of TLA comprehensive and practical, I will also devote a part of the discussion to delineating the components of TLA which I did not exemplify in my teaching. The intention behind this is to broaden the implications of this study to curriculum design and teacher training in CBI which is based on an epistemological view of language teaching in context. First, below is a discussion of the components of TLA which I did utilize and how they influenced shifts in classroom discourse.

5.3.1.1 Components of TLA and increased dialogicity

The first teaching episode in genetics employed a dialogic interaction where I could highlight many of the components of TLA (Table 1) supporting the pedagogical moves of my teaching. The TLA components I found in this episode are in lexical scaffolding and lesson preparation: "identifying key features for learning, highlighting those features appropriately in examples to be presented to learners" (Andrews & Lin, 2017, p.61). By purposefully underlining "parents' cells or biology" (genetics) and "food, weather and workout" (environment), I drove the direction of the lesson towards the two essential causes for "what makes us who we are". The input came from the students, and in weaving their ideas into my sample sentence to be worked upon, I showed acknowledgement of their rich background knowledge. I also found components of TLA on a lexical level in "providing appropriate language-related mediation/scaffolding" (Andrews & Lin, 2017, p.61) where there was a subsequent language instruction move based on the 5R Model (in *replacing* the students' everyday words with new science word). My awareness of the subject matter and the specific language accompanying it allowed for this simple activity to serve both the content and the language objectives of the lesson. I explicated in the data analysis that to achieve both objectives during the same activity, I needed to form a bridge to connect the required lexical items with the newly introduced concept of "traits" and "what influences traits". I used a bridge as a metaphor to delineate three small and fragile yet connecting parts: drawing on learners' knowledge, responding to the question at hand using the learners' knowledge, and introducing new science vocabulary by making connections with past knowledge via *repeating* and *replacing*). This process enabled the three parts of the bridge to collectively fortify each other and achieve the purpose of lexically and conceptually advancing the leaners' meaning making process. Below, I present two sentences that two pairs of students formulated after the bridge was completed to demonstrate their new knowledge of the field-specific vocabulary, such as "nutrition", "trait", 'inherit", and "genes" - which were not present in the initial pool of vocabulary:

> Group 1: Nutrition is important for human growth. I have different traits from others.
>
> Group 2: We inherit traits from our parents in our genes.

There are other examples from my data which also reveal that components of TLA orienting the learners with the language in context, correspond with dialogicity of the communicative discourse. An example of awareness of the learners' knowledge of GMO's and awareness of appropriate material and tasks that suit the learners' needs, was realized in selecting the "Animal Pharm" documentary. In discussing this controversial topic before and after watching each episode of the documentary, I provided its transcript to the students and unpacked its sophisticated language ahead of time. The debate episode became an example of a highly dialogic and interactive discourse. Another example, displaying my TLA in formulating appropriate questions to motivate critical thinking (based on Andrews and Lin, 2017) refers to when I asked Peyz to connect his observation of the heated syrup and balsa wood to how layers deep within the Earth behave. In a short dialogic exchange, asking the right kind of question, drawing on a connection (the key concept in the lesson), I invited dialogicity where deep learning occurred evident from Peyz's response (presented in episode 2 of earth science).

At this point, I ask if these examples imply that equivalently low levels of TLA in preparation and facilitation of a CBI lesson, could change the discursive interactions from dialogic to authoritative? To respond affirmatively to this question, I will offer an example from my data to show that insufficient TLA in understanding gaps in students' background knowledge impacted the shifting of discourse from dialogic to authoritative, in a lesson which started with students' enthusiasm, participation, and great curiosity but ended in their questions being ignored and a lecture on the technical and scientific perspectives to take over. The example occurred during the alien baby episode. The data showed a lack of understanding of the learners' perspectives and gaps in their knowledge in understanding the concept of "alleles" and making a connection between "alleles" and "genotypic information". The process of lesson preparation did not take sufficiently into account the learners and their questions and solely focused on the delivery of the theory. This was evident in the fact that I overlooked the students' comments around the findings being confusing to them: "*did we do it wrong?"* and "*but that's weird!".* Thereby, lacking awareness of the learners' perspectives, I could not engage them dialogically as I did not know or had not planned for their perspectives to become part of the language of the lesson, which caused for an authoritative intervention on my behalf focusing on information-giving: "*what do we need that is more accurate*?" Even after Peyz, surprisingly, offered "*genes*" as the acceptable answer, it was not clear whether the other students shared his views and whether or not he, himself, had deep knowledge of *why* genes could offer more accurate information. In the end, I presented to the learners the disciplinary views authoritatively. How I could have unfolded the language for the students in a manner that inconsistencies and misconceptions became apparent and how I could have engaged my TLA in this episode differently to make it a successful lesson, will be discussed in detail in the next section. For now, I would like to return to the question of the interaction between discourse and TLA and ask if all dialogic discursive interactions tie to the teacher being highly aware of the many features of the language of the subject matter? And similarly, if all authoritative discursive interactions correspond to the teacher being unaware of the many features and functions of the language?

This time, I will use an example from my data to respond negatively to this question. I will refer to an episode in genetics where the patterns of interaction and the communicative approach identified the discourse as being authoritative; however, the analysis of the findings revealed that many of the components of TLA according to Andrews and Lin (2017) were present in this episode. The review lesson (episode 3 in genetics), where the students needed to fill in the blanks to review the concept of "heredity" showed that the task served the learning objectives and accomplished the lesson purpose: to orient the students with some features of the register of scientific expository paragraph writing. I provided appropriate language-related mediation and reinforced academic features of this science register, where the introductory sentence needs to be supported by the details of the paragraph and each sentence needs to agree in subject and predicate. Also, when the group's interest was fading, I showed on-the-spot thinking in encouraging the learners to stay patient as this was a skill useful to developing essay writing and report writing skills - both important for succeeding in their final exams. Furthermore, I showed ease of access to subject-matter knowledge where I reviewed and reinforced the conceptual nuances of "heredity" and probed the learners' prior knowledge as they co-constructed the meaning of "exhibited" with each other's aid. The majority of these pedagogical moves were done by means of short chains of I-R-E within an authoritative discourse where the students responded to my initiations and I evaluated them positively or negatively, strengthening only the established scientific view. Hence, engaging students in authoritative discourse co-existed with many of the components of TLA proposed by Andrews and Lin (2017).

Therefore, authoritative discourses are not indicative of a lack of TLA. However, interestingly, the reverse was found to be true in my data: every episode which was identified as displaying inadequate TLA in preparation, facilitation and on-the-spot interventions, was also a lesson carried out authoritatively. My data suggests that when teacher preparation and lesson delivery do not display components of TLA proposed by Andrews and Lin (2017), such as the teaches' ability to analyze the target language from the learners' perspectives or monitor the language produced by the students to identify the gaps, then the teacher resorts (or at least I resorted) to a presentational style of information-giving, fact-checking and evaluative interactions in an authoritative approach. This makes sense! It is much easier to read from textbooks than to spontaneously accommodate for the learners' views of the language, bridge the gaps in their knowledge, and conduct lexico-grammatical scaffolding when the teacher's awareness or knowledge of the language of the discipline is insufficient. Sheer delivery of information through reading from text, using power-point presentations, and assigning question and answer worksheets based on hand-outs -indicative of a shortfall in understanding and a pedagogical awareness of the language of the content - unfortunately, dominated much of the earth science teaching activities which were also facilitated authoritatively.

In the next section, I will discuss the interventions which I needed to implement to enhance my pedagogical strategies and raise the students' awareness of the complexities of the academic language in order to promote their learning in content, language and reasoning skills. But before I do so, I will return to the second research question: "how does TLA impact the rhythm of classroom discourse and learning gains?" I conclude that my data revealed that an awareness of the pedagogical language of the discipline did not exclusively translate into one type of discourse. This kind of an awareness seemed to afford the teacher the ability to skillfully and purposefully shift the discourse of classroom from dialogic to authoritative and vice versa to the benefit of the leaners. However, a lack of TLA restricts CBI teachers to the authoritative end of the discourse domain.

5.3.1.2 Components of TLA in the "how" of the impact on discourse

The discussion above satisfies one aspect of the second research question: What kind of an impact TLA had on the rhythm of classroom discourse and on learning gains? I argued that TLA in the discipline of science allowed for a shift in discourse to occur skillfully and purposefully to enhance learning gains. The "how" of the question can perhaps be answered by one more of my findings from the data analysis (see Table 23): TLA impacted how lexical instructional models and register and genre-based pedagogical strategies were employed in the degree of consideration of the students' views which determined whether dialogic or authoritative discourse dominated. Thereby, it is with the help of the models and strategies accommodating for the learners' language needs that discourse can move to either side of the dialogic-authoritative dimension for greater learning gains. I will employ a different method of discussion in this section; I will draw examples from episodes and instances where I could not successfully utilize language instructional models and pedagogies. I will then examine how those episodes played out first in terms of interactional discourse, and second in terms of language learning.

My data provided examples in which aspects of lesson preparation and impromptu lexical scaffolding were plenty; however, many opportunities to scaffold language learning on a lexico-grammatical level within the scientific story where language functions and respective sentence patterns could be delineated were not seized. For instance, in the review of the data from episode 1 of genetics, inquiring about "what determines our traits", a further pedagogical step in inspecting the meaning of "traits" in multiple contexts would have been fruitful. This step would be to move the direction of the story to where "traits" are not only "unique physical characteristics" but also a way to determine whether genes are inherited. To do so, I would have utilized the Genre Egg framework, in a bottom-up approach to introduce the students to the sentence pattern of *defining* "traits" via the formula borrowed from Lin (2016), presented in Tables 6a and 6b. In creating such tables, the dual purpose of raising the awareness of the learners towards how language mobilizes different purposes, such as *defining*, *exemplifying, classifying, contrasting*, etc. and teaching the concept of "inheritance" in a deep and connected way would have materialized. Table 6 is copied below to illustrate the sentence pattern of *defining* realizing both contextual definitions:

Repeat of Table 6: The Lexico-grammatical Pattern Realizing the Function of Defining

Technical term	**Relating verb**	**General class**	**Phrase/clause giving defining details**
Traits	*are*	*characteristics*	*of organisms*
Traits	*are*	*features*	*that are unique to organism*
Traits	*are*	*qualities*	*that are passed down from parents to offspring*
Traits	*are*	*features/qualities*	*That are influenced by our genes and our environment*

The key to making this instructional tool a success is to ensure that language is taught in context as opposed to decontextualized and pre-formulated to be memorized. As Lin (2016) warns, "It is important to recognize the need to allow students the opportunities to discover how these functions are realized in texts that are meaningful to them" (p. 44). In this way, teachers can paint a bigger picture for how "language functions" evolve from determining recurrent sentence patterns to actuating the larger purpose of text and shaping the overall structure (or organization) of the genre.

A second example demonstrating an opportunity where TLA of the register of science reasoning and debating could effectively execute scaffolding of language features pertinent to the sentence patterns of defining an argument, providing evidence, offering justification and exemplification was portrayed during the two debate episodes. Although, debating the pros and cons of GMO's and the two sides of renewable energies replacing fossil fuels occurred successfully, genre-based pedagogies, such as the Genre Egg, offer tools with the potential to raise the students' awareness of the specific register, its vocabulary and sentence patterns. Table 13 in the data analysis chapter offered some examples of what such genre-based scaffolding could look like using short classroom excerpts of the students' evidence-based and knowledge-based reasoning, justification and argumentation which hinge on mobilizing recognizable sentence patterns. The sentence patterns which were found in Table 13 included the causal relationship (*I don't believe in renewable energies because the fossil fuels provide 80% of our energy usage),* comparing (*electricity has got a big power more than fossil fuels),* and exemplification (*electricity from those wind and solar and those hydro things).* I have created Table 24 (an extension of Table 13) to show a wider variation of language resources that students could rely on in familiarizing themselves with the genre of scientific debate. Where possible, I have preserved students' lines from the transcript of the debate episode to illustrate such sentence patterns by the students in materializing their purposes.

Table 24 Sentence Patterns Realizing the Different Stages and Moves in the Genre of Debate

Position statements starters	- My argument is … - My reasons are that …. - I would argue that …
Presenting the position	- So it can't replace fossil fuels. - I don't believe that it is possible. - It doesn't make sense.
Extended noun groups	- Such clean and renewable energy sources… - The Earth's energy budget crisis is…
Providing evidence	- Because the fossil fuels provide just 80% of our… - According to the latest research… - Based on the data…
Offering justification	- We will face a shortage of energy supplies because… - Technology will advance to provide the enough ….

Exemplification	- They're trying to build an airplane that is using the energy of the electricity. - We already have a technology to produce electricity from those wind and solar and those hydro things.
Connectives to show cause and effect	- As a result of … - As an outcome of … - Consequently… - Because…
Evaluative vocabulary	- It is clear that… - In light of such convincing evidence… - It is logical to say… - The data shows…
Transitional Phrases	- Although renewable energies are only a small percent, … - Despite the high consumption of gas, … - Technologies to build solar power are found; however…
Transitional Nouns	- Nevertheless - On the other hand - On the contrary - Otherwise

The sentence patterns exemplified in Table 24 include some of the academic functions which evidence-based reasoning in science can employ. Explicitly teaching these patterns to students can help them to first, recognize these functions when they encounter them in text, as a debate or a discussion of a topic which has many sides; and second, to practice and use them in debating scientifically-based global issues with their peers. Table 24 shows how CBI teachers can coach their students (through extended practice) to construe scientific rationality via evidence-based and knowledge-based reasoning in the respective grammatical structures.

In conclusion, the relationship between TLA and language accommodation pedagogies shows that an awareness of the language of the discipline enables the successful application of many pedagogical strategies. Furthermore, the level of awareness and attention to content-area language features corresponds to a display of consideration of the learners' needs: their misconceptions, gaps and inconsistencies in knowledge, and diverse ideas. Such a consideration then translates into a dialogic process of communication. Hence, language accommodation in an adapted setting impacts the rhythm of classroom discourse. There was a myriad of instances were my TLA fell short of exploring the multifaceted language of science; as a result, the learners' awareness of the intricate relationship between form and function was not raised. How to respond to this shortfall becomes my focus in the implications section of this chapter where I extend my data to display where and how a heightened TLA enacting language intervention within context could enhance learning gains.

5.3.2 TLA Impacting Content and Language Teaching within Discourse

To truly ground my findings about TLA in teacher knowledge literature and ensure that my research supports the nuances of teacher knowledge in adapted settings, I will first need to explore the two other types of knowledge, introduced in the literature review, that are required of content teachers. The first exhibits an expertise of the subject matter, or content knowledge (SMK or CK), and the second is to actualize SMK in the facilitation of that knowledge and guiding the students along the journey of learning, reviewed in chapter 2 as pedagogical content knowledge (PCK). I will draw from my findings to decipher the relationship between PCK and TLA to delineate whether some of the shortfalls in my teaching were due to a lack of SMK, PCK or TLA. Does one reinforce the other and can one exist in the absence of the other?

5.3.2.1 TLA and PCK

In understanding the construct of TLA better, it becomes noteworthy to mention that when teaching outside an area of subject expertise (i.e., when PCK is low), as was the case for me in earth science, both skills and abilities were greatly challenged. As Shulman (1987) argues, a teacher's well-developed subject matter knowledge is essential to the teacher's PCK. The relationship between PCK and TLA is worth investigating. In the data from teaching earth science, not only scarce attention was paid to the language choices at different linguistic levels to achieve diverse communicative purposes, but also weaving in concepts for meaning making due to areas of unfamiliarity with content knowledge was inadequate. As Loughran, Berry and Mulhall (2012) state:

> When teaching outside one's area of subject expertise, despite having a well developed knowledge of teaching procedures (e.g. Venn diagrams, concept maps, interpretive discussion, etc.) or strong specialist content knowledge (e.g. specialist of physics or biology or chemistry, etc.) a teacher's skill of combining such knowledge of content and pedagogy in meaningful ways for particular reasons is no longer so readily apparent. Issues associated with difficult aspects of the topic, students' alternative conceptions, important big ideas, conceptual hooks, triggers for learning and so on, are not well known or understood by the teacher when rich understandings of subject content is lacking. (Loughran et al., 2012, p.7)

These were the challenges that I faced in teaching a branch of science to which I was a foreigner and for which I was ill-equipped to design a curriculum. For instance, the first episode in earth science, discoveries into the structure of the Earth, was not a successful lesson. The students expressed confusion: "*What are we exactly looking for?"* and "*I can't get what we are [looking for]"*. They offered random and unrelated answers as the learning objective was obscure. I attempted to consider their ideas in the talk of the lesson, but my knowledge was not deep and their responses to the question of "what methods of discovery would reveal to us the structure of the Earth?" were diverse. After a failed attempt, I resorted to reading from my notes, delivering the information to the students in a teacher-centered fashion. A second example displaying low PCK, was the episode in which I set up a lab demonstration to teach convection currents. Although the material and the lab I had prepared were effective teaching tools, this episode illustrated that I asked closed and restrictive questions: "*The food dye was sitting still; now something is moving it, something is pushing it. What is that something?"* and later I asked, *"The warm water is pushing it because water is warming up- here. So this warm water is traveling in which direction? This way or upwards?"* Not only my questions were restrictive, but also, I did not use the language and the vocabulary tied with key conceptual functions studied earlier, such as in KMT, "heat causing the movement of particles*"* as oppose to "something pushing the warm water*"*. So the point I raise here is that in the discursive student-teacher interactions lie opportunities for students to engage with the language and the content when and if the teacher asks the right type of questions utilizing the disciplinary-appropriate language and the field-specific terminology used in teaching of the conceptual content.

The importance of the questions the teacher poses was also evident in the debate episode inquiring on the students' understanding of which scientific theories supported the continental drift. The data showed that I did not possess a comprehensive knowledge of the distinction between what constitutes a "theory" and sets it apart from a "phenomenon". Hence, in asking "which science <u>theories</u> supported the continental drift theory", the language I applied to the question did not support the learners' meaning-making and connection-building of the key conceptual features of the question. The students bounced back and forth between one-word answers, such as the convection currents, Alfred Wegner's pieces of evidence to support Pangea, and plate tectonics. Deconstructing the theory of continental drift needed to support the students' knowledge of KMT, Earth's layers of varying densities, and the presence of currents rising and moving around crustal plates in order to build a link between all of these essential pieces and bridging these ideas. Therefore, once again, it became clear that asking the right types of questions, using lexicon that trigger students' thinking in the right direction was missing. As discussed earlier, thinking and talking are inherently connected and this is why using the language of science in its specificity and the peculiar meanings that the terminology carry is significant in teaching science, especially in the context of teaching to students of diverse backgrounds.

The data obtained from analyzing the students' journals, too, point a finger in the direction of subject matter knowledge (PCK) and TLA working hand-in-hand. Table 14 in the dissertation showed an organization of journal topics by purpose. The table revealed that the majority of questions I had formulated for the students to reflect upon in earth science, were focused on "reviewing a key concept". In genetics, only a few questions were based on a review of a key concept; journal topics in genetics were predominantly centered around activating students' prior knowledge as well as engaging the students in evaluating a debatable topic. In the end, it was clear that the type of journal topics given impacted the level of criticality and reasoning employed by the learners in their entries. Students wrote more critically in genetics, using facts and reason to support their claims. For example, to the questions "what determines if characteristics are genetically inherited," Rentaro wrote: "*I think DNA inherited by our parents determines our characteristics but not definitely, environment can affect either*." For the same journal topic, Peyz wrote: *"First they gonna see the parents DNA pattern which has something same with the child DNA … or they got the disease from environment*." None of the features of evaluation of the issue at hand, positioning one in the argument and making a claim, using knowledge or evidence (the characteristics of the register of reasoning in science) were present in any of the earth science journals. To conclude, the lack of PCK in teaching earth science permeated my approach to scaffolding the students as evident in the type of journal questions I asked. I did not pose questions that engaged critical thinking, evaluating and reasoning in earth science as much as I did in the unit of genetics. Thereby, the importance of PCK in executing one's TLA becomes clear.

As a caveat, my examples do not suggest that all episodes in earth science were unsuccessful and ineffective in scaffolding the learners' knowledge and engaging them in inquiry. Despite my unfamiliarity with earth science, two of the four narrated episodes showed that asking the right questions and helping students make connections created a dialogic discourse within which meaningful, conceptual learning happened. For example, the balsa wood and syrup experiment displayed productive scaffolding on my part where I asked a very open-ended question, "*Peyz, what do you think we're trying to make a connection to? When you think about the Earth?".* I believe the unrestricted nature of this question, along with Peyz's rich prior knowledge activated the process of meaning making and helped him arrive at a key scientific understanding: how thermal energy affects density to cause the movement of crustal plates. In terms of the components of TLA, I had appropriately selected an experiment that was instrumental in meaning making through legitimizing Peyz's thinking and talking. According to Andrews and Lin (2017), selection of material and tasks which suit learners' needs and serve learning objectives is indication of high TLA. Aside from my lesson design, the shift in my interaction with Peyz from providing an answer to his questions in an evaluative manner to instead dialogically seeking his insight showed great awareness on my behalf. Therefore, I can conclude that low content knowledge did not translate into low PCK across the entire content area, but that my PCK in relation with my TLA in earth science did not enhance academic leaning gains for the students to the same level as in the unit of genetics.

5.3.2.2 TLA enabling simultaneous content and language teaching

In the beginning of this chapter, I reviewed my research findings. One of the findings revolved around teaching content and language in parallel: language instruction did not impede science content leaning; it facilitated content learning in parallel. I will attend to examining the simultaneous teaching of language and content in the context of classroom discourse first, and then I will explore how pedagogical strategies, such as the 5R Model and the Genre Egg framework were accommodated without disrupting the flow of content teaching.

Other than the shift in discourse from dialogic to authoritative, there is another type of a shift in teaching language in content; the shift from teaching language to teaching content and vice versa. Lin (2016) writes:

> In other words, these instances of language functions need to be experienced and noticed in a meaningful text-in-context. And this 'noticing' process (or 'focus on form') must not impede content learning (i.e. not turning a content lesson into a language lesson), and this requires skillful

> 'shifting' between focus on form and focus on content on the part of the teacher. (Lin, 2016, p. 44)

The "skillful shifting" referred to by Lin, happens when language and content objectives are realized in the same lesson. This is the product of pre-planning the lesson objectives in advance, anticipating incongruences in perspectives, and designing the language intervention moves within context. In the literature review, it was reported that English language development and science instruction are complementary (Gomez Zwiep & Straits, 2013; Oliveira & Weinburgh, 2017; Stoddart et al., 2002). However, it was not explicated whether science and language instruction together can allow for interactive discourses to invite dialogicity in pedagogy, or if the intervention of mini language lessons negatively shift the discourse to authoritative and information-giving approaches. I will discuss my data in terms of my instructional interventions, language moves or simply language accommodations in guiding my students in their journeys of language acquisition where they express needs, display gaps or show strengths. I will examine language accommodation not in isolation but in how it impacts the rhythm of the classroom discourse and how, itself, may be impacted by my TLA. To do so, I will examine the patterns of interaction and simultaneously ask how the concurrent teaching of language and content impacted the desired communicative approach in an adapted classroom.

First, I will refer to two examples from the unit of genetics which both fall in the category of successful language accommodation moves: 1) *replacing* students' everyday words with scientific words and 2) *revealing* new vocabulary items for the learners. Revisiting the meanings of these terms from the literature review chapter may be a good refresher (Silva et al., 2012 and Weinburgh, et al., 2014):

- Replace is a type of move wherein the teacher provides ELLs with the academic term that can be used in place of the everyday term first used by the student. The teacher honors the non-scientific language and builds upon it as a natural way to develop both language and content.
- Reveal is a move wherein the teacher provides ELLs with an academic term that does not exist in everyday language. Because science has many new and unique terms, teachers must introduce students to new vocabulary as it is needed to further meaning-making.

A few of the examples in *replacing* students' everyday ideas were demonstrated in episode 1 of genetics, where the learners replaced "unique" for "traits that are different from others", "parents' cells or biology" for "genes", and "food, weather, and workout" for "environmental factors determining traits". In these instances of lexical scaffolding, (see transcripts from episodes 1 in genetic), the language accommodation moves did not cause a break or an interruption in order to intervene with a mini language lesson in the midst of teaching content. The dialogic rhythm of the discourse was maintained and students' ideas and suggestions were elicited and naturally implemented into the talk of the lesson in replacing the non-technical words while content was being reinforced. This tandem attention to language and content promoted genuine vocabulary use in a way that replacement occurred in context- where language and concepts represented by new language were integrated in the talk of the school social plane.

Replace was also present in the transcripts from the selected episodes in earth science. The examples that follow show a significant amount of participation on behalf of the students in *replacing* the here-and-now words for more technical and scientific terms. These examples are "quantum", "nucleus" and finally "core" to replace "inside", "a dense core" to replace a "metal core" (in episode 1 of earth science), and "temperature" to replace "heat" when Jerry says "*It's lost its temperature*" and Peyz intervenes to say "*it's lost its heat*" (in episode 3 of earth science). In these examples, similar to the examples in genetics discussed above, the rhythm stayed unchanged. Discussing the core of the earth had adopted a dialogic discourse which was maintained amidst multiple language accommodation moves. In the second example, *replacing* "temperature" with "heat", the interaction had begun in an authoritative manner, pursuing only the established scientific view; however, Peyz's correction of Jerry occurred naturally and the discourse maintained its pursuit of the disciplinary views with no interruption via this peer to peer language accommodation. Research shows that in replacing the everyday words with scientific words, key concepts are being worked on and explored because choosing to deconstruct language features provides more than abstract focus on language, it will emphasize cross-cutting ideas (Oliveira & Weinburgh, 2017), create opportunities for meaning construction (de Oliveira, 2017) and prioritize student thinking (Gomez Zwiep & Straits, 2017). Thus, supporting of language learning within context became possible by way of lexical scaffolding using the 5R Model.

Now I will revisit a few instances of *reveal*, where gaps in language necessitated definition-giving. In episode 3, fill-in the blanks activity in genetics, vocabulary such as “exhibited”, “inherited”, and “acquired” were unpacked either by me or with the help of the students in a whole-class interaction where the communicative discourse had adopted an authoritative, review approach. Peyz suggested “car dealership” for “exhibited” upon my prompt and with additional feedback from me, Fanta offered “show” to reveal a synonym. The authoritative discourse of the review fill-in the blanks activity shifted to a dialogic consideration of the learner’s ideas and then shifted back to authoritative again after I recognized that the gap was addressed. Also, in episode 1 of earth science, where the clay ball was being used, the students were asked to “probe”. Within a whole-class scaffolding task, and with the help of Rentaro offering “analyzing” for probe, I paused the course of the interaction, attended to lexical scaffolding for the meaning of “probe” in a dialogic discourse of initiation, response and feedback. Again, it seemed that *reveal* necessitated pausing, making an accommodation and returning to the interrupted discourse.

Overall, these episodes displayed success in addressing a language need in conjunction with reinforcing the conceptual ideas. My conclusion is that the language accommodation moves from the episodes I have examined, did not hinder or shift the rhythm of discourse to adhere to information-giving or presentational style teaching of only a single viewpoint. The need to accommodate for language meant that I prompted the students to disclose any gaps in language knowledge and to offer their ideas both in *replace* and *reveal* in a learner-centred, dialogic and participatory approach. In no instance did the need to attend to language take away from or disrupted the rhythm of the existing interactions. In fact, since talking and thinking reinforce one another: talking about the language of science helped the learners appropriate the scientific way of thinking more effectively.

What comprises attention to language beyond the lexical level? Can language interventions beyond a lexical level, such as sentence patterns, academic functions, or text types also occur in parallel with content teaching? Essential cognitive discourse functions of science such as *defining, exemplifying, categorizing, contrasting, reasoning*, and others can only occur in relation to the subject matter content, and thus are embedded within the discourse of the classroom. Because these language functions are both linguistic and cognitive, their scaffolding of them in context becomes an effective pedagogical strategy, such as the many recommended genre-based pedagogies. For the teacher in CBI, the responsibility lies in identifying the linguistic demands of these language functions at different levels and using key academic registers to raise ELLs' awareness of them. Pre-designing tasks and activities as well as attending to language impromptu were prescribed as components of the TLA construct. I will discuss one such pedagogical strategy in mapping out the key language resources of a unit of study, embedding the content goals, student roles and identities, and genres to be explored in realizing the overall objective of the unit. I will do so to advance my assertion that language accommodation of the disciplinary language functions, registers and genres, beyond lexical scaffolding, can also occur without interruptions and disruptions to the rhythm of the classroom discourse.

Curriculum Mapping (Lin, 2016, p. 80) is a tool for the CBI/CLIL teacher to design a unit plan by carefully identifying conceptual relationships, anticipating areas of conceptual incongruences according to the learners' perspectives or the presence of learning barriers, and mapping out the necessary language functions through scaffolding key vocabulary, language patterns, text types and simultaneously address the outer layer of the Genre Egg which is the context of the unit. Because language and content are planned in parallel in advance, the teacher in the adapted setting can use curriculum mapping to make the shifts from teaching content to teaching language purposeful and seamless. Below is an example of how I would utilize such a tool for planning a mini unit around the topic of "alleles" (episode 2) in genetics, where my data showed that the students expressed uncertainty in how the experiment results were interpreted by me. After the students realized that by observing the physical characteristics of the alien babies, they could not identify the pair of parents, it was revealed that they needed to use the genotypes, the alleles. At this juncture, the data showed that I was not able to communicate what "alleles" are to the students and how they help determine heredity. I speculate that explicitly teaching the subject matter functions of *defining* and *categorizing* to scaffold for "alleles" and "phenotypes" vs "genotypes" organized according to the curriculum mapping tool, as shown in Table 25, prior to the students experimenting with the content and the language would have been a feasible way to resolve the misunderstanding and confusion.

Table 25 Curriculum Mapping for a Mini-Unit in Genetics

Content goals	Investigating how to determine heredity: Parents' genes (genotypes) versus visible traits (phenotypes)
Teaching/learning activities	The Alien Baby Experiment in pairs, Whole class discussion, Experiment and written report
Student roles/identities	Researchers, investigators, biologists, geneticists
Key vocabulary	Alleles, genotype, phenotype, traits, visible and invisible characteristics, crossing, offspring, recessive, dominant, and co-dominant
Language functions and patterns realizing them	Observing, defining, categorizing, calculating, sketching, evaluating, reasoning and reporting
Genres (to be understood and produced)	Activity Sheet, written report

(borrowed from Lin, 2016, p. 80)

From examining Table 25, it is apparent that the alien baby experiment (as an example) could be an appropriate scientific context wherein the learners concurrently 1) explore their prior knowledge, 2) engage in an inquiry, 3) experiment with the language (either in highlighting the sentence patterns and procedural registers in the experiment and/or constructing their own sentences and paragraphs using relevant formulas), and 4) evaluate their findings based on meaning making through language. This latter point is the thematic finding that I like to conclude with: the teaching of conceptual relationships in science can only occur while discipline-specific language is taught during the meaning-making processes. Respectively, the language demands of the discipline can be effectively addressed when they become meaning-making tools. Thus, the goal of creating careful unit plans through the medium of curriculum mapping tools which realize the language and content objectives with minimum interruption and shifts to each other becomes a significantly important task for CBI teachers. While this tandem language and content learning is occurring, how are the learners' views changing, their identities evolving, and their competencies developing? The next section will delve into the students' roles and identities.

5.3.3 Discourse and the Development of Social Competency

Scanning the data analysis chapter, there are references to "feelings of empowerment", "validation of one's perspectives", "gaining legitimacy", and "building an identity of a scientist or a science-knower" which collectively point to overall gains in social and emotional competencies. I found that in analyzing all such examples in my data, I have interlaced issues of empowerment with students' learning gains in a manner that gains in content and language learning have been construed as gains in social-emotional competencies. This piece was foregrounded in the literature where strong associations between academic achievement and heightened sense of empowerment were found (Reyes et al., 2010; Greenberg et al., 2003; Jennings & Greenberg, 2009). Likewise in CBI research, content learning and identity construction are linked as they both involve new meaning making (Cumming & Lyster, 2016; Varelas et al., 2012), where teaching language in content has generated greater feelings of success (Cumming & Lyster, 2016; Garzón-Díaz, 2021).

For ELLs in content courses, feelings of exclusion, either because they don't share the school's dominant language and/or culture or because the science they did in their home schools looked different or was approached differently, creates emotional uncertainties. If a science activity or a pedagogical approach can communicate to ELLs legitimacy, belonging, agency, and empowerment, I will acknowledge those as building blocks for social and emotional competency. In the discursive classroom interactions, lies the role of the teacher as guiding and endorsing the learners to become agentive, to adopt an active role in learning (Derewianka, 1990). I believe many such instances were found in my data where the consideration of the students' ideas and suggestions in the talk of the lesson translated into validation and legitimacy for them. For example, formulating a "teacher answer" based on the students' contributions to the word map, acceptance of Jerry's proposal of "special looking", using Yuki and Lisa's sample sentence as an example of a scientific answer, confirming Gavin's rich knowledge about "density", or praising Peyz's deep connection comparing the balsa wood with the structure of the Earth all communicated my trust in their knowledge and the emergence of their positive science identities.

What is more, research has shown that peer-to-peer interaction is where learners can confidently question, test and trial their newly formed knowledge in light of power relationships, which otherwise may prevent ELLs from engaging in classroom discussions. Collaborative debate has been found to create opportunities for the learners to develop cognitive and social-emotional competence to do critical thinking (Bricker & Bell, 2012; Kuhn, 2010). The debate episodes (as discussed in section 5.2.6) offered the strongest indications of internalization of science-knower and expert identities, legitimacy and self-confidence by the students. In negotiating both the controversial issue of GMO's and the global crises around sustainable sources of energies, the students spoke with rigour, passion, and courage. In these peer-to-peer interactions, they confidently positioned themselves in the argument, "*I think our renewable energy can replace fossil fuels"* or "*The new salmon grows all year. This is very good."* They also constructed clear opposing phrases, "*this is a very high difference. So we cannot use [clean energies]" or "So, oil is limited right? If you keep using it, you will definitely run out!".* Finally, they took on a scientist identity by posing questions to complex issues, "*But, farmers have been interfering with nature for thousands of years. So what if we continue doing the same using technology?"* The students' strengths to confidently engage in the debate, rebutting and repositioning themselves in the argument, indicated a level of empowerment and confidence in both having knowledge and having the identity of a legitimate science-knower. The idea of "scientific citizenship" (Gibbs, 2015) hinges on the relationship between science and society and shows that students construct positive identities when they gain membership, demand rights and privileges and participate in society. The adapted science class community as a micro-system within society became a site for constructing scientific citizenship and positive identities.

In examining impactful pedagogical strategies in a holistic view of academic learning gains along with social and emotional growth, I believe that active and successful participation in a collaborative debate can be interpreted as gains in academic literacy and empowerment, confidence building, and construction of new positive identities. Such internal growth, although difficult to measure with a quiz or an essay, and at times unobservable, needs to occur in conjunction with other forms of learning gains to assure the learner that s/he has access to the theoretical perspectives and has the ability to evaluate and reason. It is worth mentioning at this point that those episodes in which the development of social and emotional competencies and identity construction were evident turned out to be the episodes which were navigated through dialogic discourses. This suggests that in an adapted setting, when students engage in a dialogic process of exploring and working on ideas with a high level of interanimation, expressing their thinking through talking within the context of the scientific discourse, the development social-emotional competencies is being supported through knowledge building. Simultaneously, the students were building "argumentative competency" (Kuhn, 1993) as was evident in the students' use of sentence patterns specific to the genre of debate in the domain of science (see Tables 13 and 24). The tables showed that during the GMO's and sustainable energies debates, the students *defined the argument, presented their positions, offered justification,* and performed many other cognitive and linguistic functions purposefully and effectively (although in early stages of maturation).

Now, how do learners acquire language skills to perform the many functions essential in a debate, be it *taking a stance*, reasoning, refuting, rebutting, and concluding? It was agreed upon in ADI research that many opportunities exist where a CBI teacher can help students learn and use academic forms of language within the context of a debate or argumentation (Callahan at al., 2019). Language-intensive instructional approaches in conjunction with ADI hold promise to help learners develop literacy skills which I attempted to delineate in my data analysis. In discussing the high ability of the students to carry out an energetic debate on the topic of fossil fuel alternatives (a short excerpt which I transcribed to display a successful portion of the debate), I illustrated that the language functions pertaining to the genre of scientific debate had been well-known and rehearsed, either as this was the second round conducting a formal debate or because students transferred this knowledge from their past academic experiences. Table 13 showed that the students demonstrated the many components of a successful debate which hinge on mobilizing recognizable sentence patterns, such as "defining an argument" (*renewable energies cannot replace fossil fuels)*, "positioning self in the argument" (*I agree that…)*, and "providing evidence and justification" (*We already have technology from wind and solar which produce hydro).* I expanded this discussion when highlighting the applications of TLA in scaffolding language functions in the context of debate, and I extended Table 13 into Table 24 as an attempt to offer pedagogical strategies to CBI teachers using ADI or debate. Table 24 showed that supporting the learners to prepare for a debate invites opportunities to teach the register-specific language functions; in this case, causal relationship (*I don't believe in renewable energies <u>because</u> the fossil fuels provide 80% of our energy usage),* comparing (*electricity has got a big power <u>more than</u> fossil fuels),* and exemplification (*electricity from those wind <u>and</u> solar <u>and</u> those hydro things).* The message that I aim to convey is that engaging ELLs in debate to advance their knowledge while they build social-emotional competence to participate and negotiation in a debate, can only materialize when the rules of the language of the context are explicitly taught.

When introducing the pedagogy of ADI (Callahan et al., 2019) in the literature review chapter, many benefits and gains were highlighted. The authors stated that as an integrated approach to language and practice-oriented science instruction, ADI fits the criteria for an effective pedagogy; however, "if done poorly, with little attention to classroom social dynamics, ADI could further ostracize bilingual ELL youth in the discipline of science" (Callahan et al., 2019, p.194). My data showed that in the context of debate and scientific negotiation in CBI, teaching the scientific perspectives, inviting others' perspectives dialogically, and explicitly teaching the structure of language mobilizing debate functions would create a climate of success.

The above findings are in response to the third research question: **How does raising the students' awareness of language and content help them develop confidence and competency?** My findings attest to the impact that classroom discursive interactions have in realizing learning gains, knowledge-based reasoning skills, and competency development in line with findings reviewed in the literature. However, the power of equipping the students with the lexico-grammatical patterns instrumental in enacting different purposes in a scientific debate or argumentation cannot be left out of the curriculum of adapted science. Classroom participation was found to be an element integral in learners' positive identity formation (Varelas, et al., 2012), while "scientific citizenship" (Gibbs, 2015) stemmed from the conceptualization of membership, rights and participation realized within classroom discourse.

5.3.4 Revisiting the Second and Third Research Question

By drawing on a communicative framework, pedagogical models and frameworks, and a construct to evaluate TLA (see Figure 12), I explored classroom interactions in relation to my students' engagement with the discourse, the rhythm of the discourse, and my ability to shift the discourse to promote greater learning gains via analyzing transcripts of whole-class discussions, student debates, and students' journal entries. This process impacted my views of teacher identity, teacher knowledge and teacher language awareness (which will be discussed further in this chapter), as well as offered insight on the role of teacher scaffolding and language accommodation moves with the potential to raise students' awareness of the linguistic resources in the academic discipline and to build knowledge-based reasoning skills and scientific argumentation. In the later episodes where science-related social debates were facilitated, it became noticeable that student contributions had grown in length and rigour; that the students had become more proficient, confident and willing to take risks. Thereby, I was able to demonstrate that dialogic scaffolding of learners' prior knowledge, consideration of their views in the talk of the lesson and approaching the scientific story from the learners' perspectives while exposing them to science-specific academic literacies, created an environment where competency building and positive identity construction could take place. Meanwhile, the issue of authoritative discourses and their impact on debate and scientific negotiation were illuminated. Furthermore, as the analyst with the knowledge of register and genre-based pedagogical strategies, I demonstrated that in areas where my TLA in realizing schematic and structural purposes failed, many pedagogical scaffolding strategies could have been explored. For example, I used examples from the classroom transcripts to show the sentence patterns of language functions such as *defining, describing, explaining,* and *reasoning or debating* using the Genre Egg and the CDFs. I then adopted a top-down view of language teaching in context and showed what Curriculum Mapping could look like, for two mini-units: *exploring the Earth's layers* (Table 10) and *investigating heredity* (Table 25).

In the next section, I aim to address the fourth and last research question in the context of existing gaps in literature. I will also broaden the implications of my findings to make recommendations for teaching science in adapted settings where often teachers are either trained in content or language but not trained in both as this reality prevails due to the structure of most teacher education programs in Canada and USA today.

5.4 Implications

In the final section of this chapter, I will scrutinize my findings and analyses for useful and practical implications of my research for teacher training programs, curriculum design studies for adapted science courses, and literature on CBI, teacher knowledge, teacher and student identity. My last research question posed: **What are the challenges of a teacher-researcher's study in designing and delivering inquiry-driven lessons for English learners in high school adapted science?** I will delve into my reflections on this question by pairing my reflections with the gaps in research which I had introduced in the literature review chapter. Thereby, I will organize this section according to the three areas of gaps identified in the literature. I will use my findings and reflections to fill in the gaps while offering insight on my teacher-researcher views of self and views of subject matter intertwined with issues of identity, PCK, TLA, and interdisciplinary dynamics within the construct of classroom research. First is an examination of my data to address a gap in relation with classroom Discourse.

5.4.1 Addressing the Gaps: Discourse and Learning Gains

In the literature review, I posited that despite a wealth of research that demonstrates the benefits of dialogic discourse in the classroom, there is a limited body of evidence to suggest that shifts in the rhythm of the communicative discourse from dialogic consideration of "others' views" to teaching the disciplinary conventions can have a positive impact on measured conceptual learning outcomes (Leach et al., 2005; Scott et al., 2006). Here, I revisit the overarching theme of Mortimer and Scott's seminal book (2003) in developing the communicative framework. The authors stated that both types of discourse are equally integral and motivating in supporting meaningful learning in a high school science classroom. Dialogicity without authoritative interventions runs the risk of generating dialogue where the basic foundations of science are not included; similarly, if authoritative discourses dominate, the fundamentals of inquiry, explorations and curiosity will be reduced to unilateral thinking and absence of reasoning and criticality.

With much confidence in my data analysis, I see a pattern which supports the theme of Mortimer and Scott's work. The interplay of dialogicity and authoritativeness benefited my students in the unit of genetics. The dialogic interaction which dominated the classroom discussion in exploration of students' initial ideas about genes and environment in *making us who we are*, shifted to an authoritative discourse in justifying for the results of the alien baby experiments. The discourse was also authoritative when reviewing students' meaning making of the science story in heredity; however, the discourse demonstrated genuine dialogic engagement when the students were negotiating the pros and cons of GMO's. The results can be found in the students' meaningful engagement with the social language of school science during the debate class, as well as in journals by Rentaro and Peyz showing evolution in conceptual understanding and language proficiency during only a few lessons. In contrast, the debate episode and the students' journals displayed smaller advancements for the learners in content and language knowledge in earth science. My conclusion is that an intricate interplay between the nature of the content in earth science being theoretical along with my content knowledge and PCK being inadequate in unpacking the conceptual complexity in teaching earth science influenced the tension between dialogic and authoritative discourses in a way that genuine dialogicity was not employed as often as it needed to be. Thereby, to respond to the gap in research, I believe that my research has found a strong connection between dialogic discourses and students' gains in science and language. Both the entries in students' journals and the level of student participation and science-based reasoning during the debate offer strong indications that considering plural accounts and employing students' ideas in shaping the talk of the lesson will positively impact their academic growth, their science identities, and their argumentation skills.

To add to this point, scientific argumentation is also considered to be best fostered through dialogic discourse (Duschl & Osborne, 2002, p. 55) where plural accounts relating ideas and their evidence need to replace singular explanations of phenomena. What I would like to reiterate here is that although authoritative discourses do not function well when the goal of instruction is to promote reasoning skills because the fact that the teacher, rather than the student asks the questions ensures that the conditions of inquiry are restricted and controlled by the teacher and hence not student-driven; I believe invitation of plural accounts alone will not foster successful Argument-driven Inquiry (ADI). In my view, teaching the orthodoxy of scientific principles to foster perspective-taking, deep connections, and knowledge-based reasoning are essential in making debates and argumentation rigorous and content-based. If plural accounts and dialogicity in the absence of scientific point of view were the only means of cultivating reasoning and debate, argumentation and evaluation would not be knowledge-based. I argue that teaching ADI in CBI needs to occur at the intersection of debate and knowledge of the established norms and scientific perspectives. In conclusion in an adapted setting, ELLs' learning gains in academic literacy are more effectively enhanced when the rhythm of classroom interactions takes full advantage of purposeful shifts between the two domains of classroom discourse.

5.4.2 Addressing the Gaps: Curriculum Design

In the section highlighting the gaps in literature, I wrote that the issue of achievement gaps and access to resources for students from non-dominant language backgrounds made it ever more significant that this group of students have access to relevant linguistic and curricular knowledge capital. Simplifying senior level content courses to the point of "dummying down" the subject matter is short-changing the students. I also pointed out that much research has been conducted with learners in the elementary age group; there is a dearth of knowledge in understanding the types of challenges high school teachers face in teaching senior level students. Lastly, I highlighted that when the medium of instruction is also the object of instruction with the added layer of content teaching, it becomes crucial to design curricula which can outline clear content area objectives with specific language foci. The technical aspects of when and how to make language accommodation moves on the part of the teacher, without interrupting the flow of classroom talk, as well as how to articulate language objectives to students without giving away the answer to their science inquiries are currently topics of much research (e.g., Lin, 2016; Oliveira & Weinburgh, 2017; Settlage et al., 2005; Weinburgh et al., 2014) which need further scrutiny. Thereby, I will devote this section of the Implications to address the following question: How to offer ELLs in senior level science rigorous and relevant curricular content in a way that content and language co-inhabit the discourse of the classroom in a harmonious and facilitative manner? The examination of this question will encompass both the challenges and the benefits of integrating language and content in teaching.

5.4.2.1 An integrated approach to curriculum design and delivery

The data in my research showed many instances in the transcripts where I attended impromptu and on the spot to the learners' language development, by mainly raising their awareness of key vocabulary. The data also showed that when I had planned in advance, by creating material and allocating class time to language teaching, I taught language resources other than discipline-specific vocabulary. For instance, I taught the roles of "subject" and "predicate" within a sentence, the organization of an expository paragraph, and ways to research and take notes for persuasive presentations in a debate. Although, I do see it to be a shortfall to mainly raise the students' awareness of the language of science on a lexical level, I claim that the aim of my research focusing on creating relevant and rigorous curricular material, took my attention away from teaching language features. Hence, as much as I am proud of the curriculum that I designed which allowed the learners access to meaningful and authentic curricular capital on par with their peers in mainstream grade 10 science, I hope to show that language and content can occur in tandem and one is not compensated for the other.

How can we make the best decisions for our students given the multi-layered nature of the adapted curriculum so that content and language are addressed simultaneously? The discussion of TLA can assist to resolve some of these challenges by means of tools such as the 5R Model, the language representations of cognitive strategies via CDFs, the integrated register and genre-based approaches of the Genre Egg and Curriculum Mapping. These tools have been exemplified in my data analysis. An additional integrative model was devised in episode 1 of genetics. I described this model using the metaphor of a bridge with three connecting parts. This model of simultaneous scaffolding of language and content was introduced in the literature review in a study where 49 elementary school students from non-dominant language backgrounds were divided into two groups learning the topic of photosynthesis (Brown & Ryoo, 2008). The study showed that exposing the learners initially to the key concepts in an everyday or vernacular language (e.g., *food* instead of *glucose*; *good air* instead of *oxygen*; and *air humans and animals breathe out* instead of *carbon dioxide*) improved students' learning of concepts. By the same token, "the bridge model", which I proposed in the data analysis chapter, elicits learners' non-technical language in order to enhance content and language gains simultaneously. The model encompasses three types of bridging and connecting: 1) bridging language and content, 2) bridging old knowledge and new knowledge, and 3) bridging everyday terms with technical terms. The three parts, which I conceptualize as fragile yet strengthening each other are below:

Part 1- Probing students' prior knowledge

Part 2- Validating students' ideas by formulating a sample sentence as an answer which used only the students' vocabulary

Part 3- Introducing new scientific words to be *replaced* in the sample sentence

To demonstrate that the model I devised can be applied to teaching activities other than my one example of answering the question of "what makes us who we are", I will borrow from an episode in earth science. The episode involved probing the two clay balls and the question to be investigated asked, "why do two balls of the same size and same material weigh differently?" The students offered rich knowledge which came from their diverse perspectives and backgrounds. I will use the students' actual words to create a word map for part 1 of the bridging model:

Part 1- Probing students' prior knowledge

From the transcript of the first episode in earth science, I selected and used the students' responses during the whole class discussion to create the following word map.

Something inside	Density	Different material
Hydrogen	Size/ one is bigger	Hollow
Flexible	Quantum/nucleus/core	Metal core

Part 2- Validating students' ideas by formulating a sample sentence as an answer which uses only the students' vocabulary

Then, I composed an answer to the main question while drawing only from the students' word map in a manner that my technical vocabulary could be to *replace* the students' everyday vocabulary in the last part of the bridge. It is important to note that the sample sentence has to be carefully formulated to provide an answer to the main question despite its lexico-grammatical errors. Therefore, the sample sentence needs to serve the purpose of offering accurate content in the presence of possible inaccurate wording or phrasing. The following is an example of a potential sample sentence as an answer to "why do two balls of the same size and same material weigh differently?"

> When two **balls** are the same **size** but one ball **weighs differently**, the heavier ball must have **density**. Either the heavier ball has a **metal core** or the other ball has a **hydrogen core** or is hollow.

Part 3- Introducing new scientific words to be *replaced* in the sample sentence

density	mass	object
dense	volume	core
more	lighter	less

I would then provide the students with the above table of field-specific vocabulary to attempt to use the words in it in *replacing* their everyday words in the initial sample sentence. After the students completed the *replacing* activity, the final answer could resemble the following sentence:

> When two **objects** have the same **volume** but one has **more mass**, the heavier object must have **greater density**. Either the heavier object has **a heavier/dense core** or the other object has a **hollow** core.

There is emphasis placed on conveying the conceptual understanding behind “density” and how the learners can make sense of it using their own initial and tentative ideas. This example demonstrated that employing the “bridge model” could support the students in appropriating the disciplinary perspectives, while feeling validated and empowered in seeing their suggestions form the backbone of the teacher’s answer to the main question. All of this is taking place while language and content objectives are being realized in tandem without any disruptive shifts. Follow-up language instruction would then engage the students in a variety of activities like the following: *defining* “density”, *describing* the balls, *categorizing* the two balls, *explaining* or *reasoning* why the two balls had different masses. These activities will also require lexico-grammatical scaffolding to ensure that the structures and functions of “density”, “dense”, “more dense”, “heavy”, “heavier”, “more mass”, etc. have been given enough attention (both focus-on-form and focus-on-meaning). This kind of language instruction situated in the context of the investigation of the two clay balls provides the learners with enhanced learning in both language and content.

In adopting the role of a research analyst in relation to my data, I was also able to broaden my analysis to view language teaching beyond lexical scaffolding; to look for opportunities where layers of language organization could be elucidated. I drew from the Genre Egg framework to delineate that attention to language in an integrated bottom-up and top-down approach could be impactful. The examples I offered in enacting the components of TLA in the earlier sections will be summarized here: First, I showed how texts at different levels are organized and constructed to exhibit a variety of registers and purposes:

- Using the lexico-grammatical patterns mobilizing the function of *defining* by means of a simple formula (Tables 6 and 7)

- Using register-specific key vocabulary and grammar words specific for *observation-making* while demonstrating how to use a graphic organizer to record the time (Table 11)
- Using the lexico-grammatical choices drawing a causal relationship (Table 12)
- Using sentence patterns and lexical choices enacting *reasoning, contrast, evaluation* and *debate* (Tables 13 and 24)

Furthermore, I utilized a Curriculum Mapping tool (Tables 10 and 25 borrowed from Lin, 2016) integrating language and content objectives in a unit or a mini-unit plan where areas of congruency could be identified to facilitate teaching the language of science in the context of science. The Curriculum Mapping tool is a comprehensive method of integrating content and language objectives in the same lesson. This pedagogical tool is a promising graphic organizer to help identify and address the essential elements in a unit: content goals, activities, student roles or identities, key vocabulary, language functions and genres. The table enables teachers to assign tasks to students while clarifying for them the sentence patterns and registers to which the students will be exposed and will eventually need to master. The Curriculum Mapping tool can largely alleviate the pressure of how to make the best decisions for the students, what content milestones are achievable, how much focus-on-form is possible in the allotted time, how to intervene with language lessons without interrupting the flow of content teaching, which language features are key, how to subsequently scaffold for language so that the learners are prepared for the demands asked of them, and finally how to collaborate within a team of teachers from different disciplinary backgrounds.

Lastly, I took advantage of the CDFs, as a construct accommodating cognition-based communication within disciplinary discourse, in extending my language scaffolding of two of my students' journals. CDFs, as an inventory of discourse patterns realizing meaning-making processes, are formulations specific to the genre and register of each discipline. I explored the CDFs of *explaining* and *describing* in the students' responses to some of the journal questions, such as "why do we resemble our parents?" (*explaining)* and "where does the Earth's thermal energy come from?" (*describing).* The results are organized in Tables 15, 17, 19, and 21. The analysis of the students' writing showed that although CDFs were not explicitly taught, rehearsed or requested to be produced by the students, there was strong evidence that they were present in the two students' early-stage writing. Thereby, fostering this type of literacy development for which the seeds are already planted can generate great results. Taking advantage of such a pedagogical tool (if applied to relevant, interesting and appropriate content) can help resolve some aspect of the difficulties of addressing both the content and the language objectives in the same activity.

In the end, using the pedagogical tools and strategies, mentioned in this section, allowed me (as the language analyst) to revisit the language of the classroom in order to seize the opportunities that were missed amidst attending to content. As an implication to research on curriculum design, it can be noted that if not integrated within the context of conceptual scaffolding, due to time constraints, all is not lost! Follow-up lessons on how the lexico-grammatical pattern of text conveyed the academic register in the previous lesson will still be fruitful. Although a shift from focus-on-meaning to a focus-on-form can be challenging to maneuver seamlessly, once the learners understand the expectations and see the benefits of this dual approach, they will be less critical of grammar work.

5.4.2.2 Critical view in the approach to an integrated curriculum design

To truly integrate language in content is to reject the arbitrary privileges the mainstream genres have gained and the deficit perspectives dominating work with (Flores, 2013; Flores & Rosa, 2015; García, 2002; Lindahl, 2020). The importance of teaching ELLs the genres and registers of academic disciplines without privileging a linear hierarchical path is a significant part of designing a CBI curriculum. In pursuit of critical studies in CBI, I echoed perspectives such as *critical content-based instruction* or CCBI (Sato et al., 2017), CLIL *critical language awareness* (Galguera, 2011) and *critical multilingual awareness* (García, 2017) where the tensioned interplay between educational policies and positions of power, training programs, pedagogical models, teacher knowledge, disciplinary hierarchies, views of multilingualism, and views of privileged language forms and genres all permeate the epistemological stances of the classroom teacher (Darvin, Lo, & Lin, 2020). I kept these critical perspectives in mind as I reviewed my classroom interactions with my students, re-thinking how to balance my attention to language while keeping content rigorous and globally conscious to design and deliver a truly integrated curriculum for grade 10 adapted science.

Offering rigorous curricular content in adapted science; content that is relevant, authentic and uncompromising can only come about when students of diverse language and cultural backgrounds are viewed as being equipped with many and multi competencies as opposed to having a deficiency that needs to be fixed. The discourse of such a classroom has the potential to communicate to the learners messages about legitimacy, agency, and positive identities. When ELLs see that the content of their science classroom is not simplified or watered-down, they feel validated and begin to internalize positive identities. They become confident that they are capable; that the education system values them. These building blocks of competency can form the foundations for cognitive, social and emotional growth through learners' positive experiences where their ideas are considered, reasoned with, acknowledged and debated. Equipping high school students with the skills to critically think, logically and knowledgably reason, and to question the status quo (in this case with regards to scientific social issues like GMOs and alternative energies) is supporting them to succeed in various academic, professional and personal journeys. The students committing to taking a stance in the two very controversial debates during the episodes, conveyed messages of competence and critical thinking skills. The documentaries they watched, the text they read and the research they conducted oriented them with the status quo and the mainstream perspectives. In being critical and taking a stance, rejecting the modification of organisms or aspects of it, or contesting to our heavy reliance on fossil fuels in the climate of protecting the planet, became clear examples of their growing capabilities in "argumentative competency".

The teaching of science in an adapted setting should include not only hands-on experiential activities to deepen scientific concepts, but also critical reading and writing skills to enhance students' engagement with text, deepen their knowledge-based reasoning abilities and model the rhythm of dialogic and authoritative interactions so that the presence of "other" views as well as the usefulness of knowledge of the disciplinary norms become evident to the learners. Teachers in adapted teaching need to have content and language objectives clearly stated and gaps in both language and content anticipated with strategies implemented into "the ways of talking" (Mortimer & Scott, 2003, p. 116). This is how discourse becomes part of the language of the social practice of the adapted science classroom, and this is how pedagogy plays itself out in teacher talk, curricular content, student-teacher interactions, students' lives and the hidden discourse of the classroom. A discussion of pedagogy as identity work is next.

5.4.2.3 Teacher identity and agency revisited

Reading through my data analysis, I realized that in all instances of visible and measurable content and language gains by my students, I had equated and linked such growth with issues of student empowerment and competency-building. This interpretation indicated to me that at the core of my teacher epistemological world views, teaching empowers self and others. In my pedagogy and my analysis, I've identified with the role of a giver: giver of knowledge, skills, agency and power. As formulating one's pedagogical understandings is a process of epistemological reconstruction, the social world, relations of power and ultimately policy makers come into the equation (Cummins & Davison, 2007). I saw my teaching, learning, interactions, lesson designs and selection of activities take place in a matrix of relations where pedagogy integrated with identity work.

From the literature review, I established that teachers through exercising their agency can enact their professional identities to enhance students' learning outcomes in all areas of growth and development (De Costa & Norton, 2017; Ilieva & Ravindran, 2018; Varghese, Morgan, Johnston, & Johnson, 2005). I felt such an interlaced relationship between teacher agency and students' learning outcomes became the main lens through which I viewed myself, my knowledge, my expertise, my pedagogy and finally my identity. In the early episodes of teaching in the unit of genetics, I identified with my role as a science expert. I had studied biology in undergraduate school and had joined a cohort of biology teachers in the teacher education program familiarizing me, the student teacher, with the applicable teaching tools and strategies to open the learners' eyes to the wonders of the human body and all its systems, the ecosystems and the DNA as the basis for the diversity of all living things. When I designed the genetic curriculum for the purposes of my research project, I found enjoyment and pride in facilitating knowledge acquisition couple with fun and inquiry-driven activities. Upon entering the classroom, I felt prepared to answer any question the students had in this unit and took pride in knowing that I was motivating them to think deeper and wider, and to make connections. In review of my episodes in genetics, it was easy to hear strength, confidence, and joy in my tone of voice – often laughing, joking with the students, and offering ample praise. There were clear signs of kinesics where my movement was energetic, my physical distance with the students small, and my smile big. In contrast, in my recorded data during the earth science episodes, I heard a quieter voice, often reading from a written text or a power point presentation slide, answering questions with hesitation and frequently stammering, “I’m not sure but I will find out and get back to you.” Rarely, in watching the video-recorded data from the earth science unit, I noticed occasions of asking the students to dig deeper to make conceptual connects. I believe what I sensed in my tone of voice and timid kinesics was guilt; I knew I was shortchanging my students because I did not know much about earth science. As logistical issues of time put earth science on my plate, I could only do the best I could. My identity as an expert of science changed; I did not think I fulfilled my role as a “giver”.

Later, as the analyst, I began the process of data analysis for both units and recognized that the highly recommended communicative approach of dialogic discourse came naturally to me. I probed the students’ background knowledge on key concepts, considered their everyday viewpoints of science issues, and weaved their scientific perspectives into the talk of the lesson. I was beginning to construct the identity of a great facilitator. However, I also needed to read and learn how to analyze the language of the discourse – within the interactions and the instructional strategies utilized. It was then, after familiarizing myself with the pedagogical approaches of register and genre-based teaching, that I realized I had not fulfilled my role as the language teacher either. My view of self, having dual qualifications in both teaching science and TESOL (due to my master’s degree) shattered. I saw great many opportunities missed where text-in-context could be mapped out for the students with recognizable patterns and easy sentence-making formulas to assist them in identifying the intentions behind text and in enacting their own purposes in conveying a message, whether in *describing, defining, classifying*, *explaining* or *reasoning*. TLA as a construct, which holds a level of empathy for and understanding of ELLs’ academic needs, compelled me to acquire effective and practical pedagogical tools in analyzing the many levels of the language of the content-area, from phonics to genres. I recognized that it was not sufficient to give mere attention to vocabulary or what subjects and predicates were; to superficially orient the students with parts of the paragraph; to briefly scaffold the structure of a formal lab report, or give a passing mention of instrumental, lexico-grammatical patterns mobilizing registers (e.g., “I observe that”, “my observation shows me that", and “I made the following observations”). More was needed and could have been done! Although I attended to language and I filled in the gaps in my students’ knowledge knowing (due to my own experience of learning the language of science in adolescence) that “inheritance”, “exhibit”, “probe”, and “core” may not yet exist in the leaners’ English language toolkit, I now know that TLA as embedded in the larger sociocultural context of the classroom enhances the ability to *teach* the subject-specific language to talk *about* content and not only to *teach* content. Talking about content will serve the greater purposes I aimed for in my research: to equip leaners with the skills to understand the hidden agendas of Discourse (Gee, 1996), to read between the lines, to question the established norms and demand change when positioned lower in arbitrary systems of societal hierarchies.

Through this new lens, I viewed my identity as a contributor to the expansive knowledge that provides in-service and pre-service teachers with insight to improve their teaching practices to better meet the needs of students from diverse life experiences. The blind spots and the shortfalls in my TLA shed light on what “could have” been done (and how) to familiarize the learners with the necessary registers and language functions present in those missed opportunities. I hope that the analysis of my data where my teacher language lens has been refined to outline (via graphic organizers) the sentence types, sentence patterns, sentence structures and formulas that typically in science mobilize positioning self in an argument, providing evidence, defining, explaining, making an observation, reporting, and other useful cognitive/linguistic functions, can be a positive addition to research on CBI teaching. In doing this type of discourse analysis, I realized yet another transformation in my identity. As a consequence of my self-perceived failure to be a “giver” of knowledge in earth science and a “giver” of skills in the language of science, I constructed a new identity based on what I had learned. I had become a knower of ways to decode the disciplinary language of science - a shared way of communicating with other adapted teachers. I would be able to one day wear this new identity on the outside and build strong channels of communication between the science experts and the language experts.

As identity can be an analytical lens for making sense of a teacher’s views of self, situated in context, it can also be used as a tool to make sense of teacher transformation and teacher knowledge awareness (Morgan, 2002; Simon, 1995; Varghese et al., 2005). I equate the process of gaining knowledge about the benefits of engaging the students through dialogic discourse, presenting to them the scientific perspectives, and the practical applications of genre and register-based pedagogies as revolutionary.

5.4.3 Addressing the Gaps: Challenges

Returning to the last research question is to reflect on the challenges I faced in designing and delivering lessons for adapted science in high school. Again, in accordance to the organization of the Implications section, I will respond to this question while revisiting a gap in the literature. Many CBI and CLIL researchers and educators contend that integrating language and content in teaching is an effective method for adapted content courses. However, how do classroom teachers overcome the many challenges involved? Lin and Lo (2017) expressed that teachers are confronted with several constraints, "including the dual challenge of teaching content and L2, gaps in students' L2 proficiency, as well as a tight syllabus in an exam-driven culture" (p. 42). Other educators claimed that sheltering content while assessing linguistic demands of content-area materials, making the material available to the learners by way of adaptations, and setting language objectives present intricate and complex constraints. More often than not, these challenges force teachers to either forgo language objectives and teach content only or to adhere to the more elementary areas of the subject matter in order to attend to language (Baecher et al, 2014; Bunch, 2013; Fisher & Frey, 2010).

In reflecting on one of my teaching episodes, where the students had the opportunity to think first and to replace "traits" for "ways": *We are similar in some traits to our parents;* a conceptual link became apparent to me to encourage deeper thinking beyond "traits" as characteristics or visible physical features. To make connections with the topic of "heredity", I wanted to ask: What is the connection between "our traits" and "our parents"? Can traits, in fact, determine inheritance since offspring is related to parents by means of these "things" called "traits"? Was time on my side and could I take advantage of this juncture to probe further? Would the learners' funds of knowledge accompany me in this inquiry? Were technical terms such as "inherited" or "heredity" available in the learners' repertoire of science terms? Had I previously familiarized the students with the sentence pattern of *describing* and could I ask them now to describe traits in different terms? Was this cognitive task too ambitious? Would I lose the majority of the learners and proceeded with only a few more advanced students?

These were impromptu and challenging questions that I needed to assess and decide. Many aspects of classroom teaching in an adapted setting, such as maximizing time and space to fit not one, but two lesson objectives; engaging all learners with a wide range of abilities; having knowledge of students' language and academic competencies and being attuned to their past educational experiences; relying on teacher training and expertise in either language or content (as realistically this is what teachers in adapted courses are equipped with); assessing the success of overlapping language and content, etc. can create many challenges. In the next sub sections, I will reflect on two of the aspects which became more pressing for me: classroom participation and departmental collaborations.

5.4.3.1 Encouraging student participation

Discussions in the preceding sections indicated that there is much benefit in adopting a dialogic discourse in teaching science to ELLs in high schools. But how does one invite dialogicity in a setting where the learners shy away from participation in class discussions? Language learners often display doubt and hesitation in expressing themselves, afraid of making grammatical or pronunciation mistakes. In general, classrooms with language learners are quieter and participation is dominated by a few talkative and confident students. The solution to this challenge was briefly touched on in the data analysis where I considered the students' ideas not offered verbally but in the written form as ways to invite their perspectives into deciding the direction of the lesson and to identify their needs. Such a solution, implemented early in a teaching unit, can pave the way for eventual increase in participation once the students have experienced a safe, non-judgmental environment, and have gained stronger oral skills helping them feel more confident to actively engage in whole-class discussions.

There is a wealth of teaching and learning opportunities hidden in the dialogic interactions between teachers and students' texts in adapted classrooms. In my research, the students' written work offered a rich resource in examining the teaching and learning processes where I got a glimpse of both the diverse background knowledge of the students and the salience of progressing their everyday knowledge towards the disciplinary knowledge. Thus, there could be vast opportunities to communicate with the learners using journals by highlighting an area which needs attention, offering a sentence pattern they can follow, underlining words to be replaced and keeping a side-conversation alive where they can ask questions or make comments. Some of this form of scaffolding and supporting students' writing was exemplified in my analysis of the journals using CDFs, representing cognitive and discourse functions based on the purpose of the students' writing. As Lin (2016) stated, when students master the multiple layers of language resources such as lexical, registers and genres that allow for meaningful communication in the language of the discipline, then they can "participate successfully in a diverse range of academic learning tasks and activities as confident speakers, listeners, readers and writers" (Lin, 2016, p.78). With this in mind, the teacher needs to be cognizant of how to shift attention from a focus-on-meaning onto a focus-on-form. Teaching language, particularly grammar, is rarely met with positive attitudes by students, especially when they are in a science class. In my transcripts of data in episode 3 of genetics, the students showed signs of boredom where they would have their heads down or talk to each other. In line 14 of the transcript, I felt that I needed to tell them "why" doing grammar work was important. Therefore, the challenge of keeping the students engaged and helping them understand the reason behind the kinds of tasks expected of them could partly resolve this challenge.

As mentioned briefly earlier, another element which offers promise to promote student participation is creating a safe environment where learners can take risks with new knowledge, yet feel validated that their ideas are respected (Greenberg et al., 2003; Jennings & Greenberg, 2009; Scott et al., 2006; Wang et al, 1997). Consequently, my data showed growing levels of student participation in the genetics unit up to the debate lesson, which could be attributed to the learners feeling empowered, feeling safe and feeling confident knowing that they are viewed as resourceful and knowledgeable. Another factor, which potentially contributes to an increase in participation through gains in knowledge and in confidence is the benefits of teaching the authoritarian scientific views, which I discussed earlier in this chapter. This point, although it may come across as a sharp contradiction, in actuality, reinforces two essential pillars of scientific argumentation: *knowledge-based* and *evidence-driven*. It is true that to be able to involve students in the talk of the lesson, learners need to negotiate their viewpoints about inquiries and science-related social issues and to work collaboratively on open-ended activities as well as argumentation as a characteristic of science, but the routine of teacher presentation needs to be taught too. Without the direct delivery of the disciplinary norms and perspectives, learners may feel apprehensive to express and negotiate their ideas feeling that they are unaware of dominant, disciplinary perspectives. Once again, discourse plays a crucial role in designing classroom interactions where space can invite and motivate students to actively engage and participate.

5.4.3.2 Interdisciplinary collaborations

An issue that I raised in brief when expressing challenges of insufficient content knowledge when teaching earth science, was the issue of interdisciplinary collaboration, team-planning and team-teaching. The topic of collegial collaboration also surfaced in my analysis when issues of time constraints were mentioned. As an example, I will return to the topic of journal writing. During the facilitation of the two units, I prompted the students to reflect on important topics and write in their journals with the aim to encourage them to formulate their thoughts and construct sentences in the genre of the language of science- something that is rarely done in a regular science classroom. The purpose was to both enhance students' writing skills and to make-up for the lower levels of participation. But it also meant that collectively, about 300 minutes were taken out of teaching time in each of the curricular units. It is unrealistic to expect ELLs to master the necessary skills when allotted the same amount of time as students in mainstream science. As Engle and Conant (2002) ascertain, sufficient class time to pursue a problem in depth is fundamental to the engagement of the students. Cumming and Lyster (2016) also found that lack of time was a major obstacle to engaging students in collaborative projects in CBI. Lastly, Baecher et al. (2014) recommend greater focus on collaborative lesson planning between the language and the content teachers. This recommendation resonates with my own experience during my data collection reflecting on the possibility of a support block where an ELL teacher could help strengthen the students' reading and writing skills. If schools could restructure adapted content courses in a way that each teaching block was accompanied by a resource or a support block to address the learners' individual needs in language and/or content knowledge, not only the classroom teacher would be alleviated but also the students would benefit.

How would my research have unfolded differently if I had initiated and sustained meaningful cooperation for team planning and team teaching between my department and the English Language Arts (ELA) department at the school? This option was not offered as it seemed that each department functioned independent of others. Adapted science had fallen under the umbrella of the Science department with no attachment to the ELA department. Thus, even though, the ELA department taught the same group of students and shared the same wing of the school as adapted science, no inter-departmental meetings, collaborations, workshops, planning or team teaching of any kind occurred over the duration of my research project. While my professional background afforded me experience and skills in both (TESOL) and teaching science, my data showed that there were many areas in which my content knowledge and TLA were inadequate. When I felt unprepared to design an earth science curriculum, my only option was to ask if Jim would share his resources with me. There were no organized systems of support to offer this kind of collegial safety net. Adapted science, math and social studies reverted to the departments of their respective content areas for registration, attendance, grading and other house-keeping items. For what to teach and how to teach, teachers were on their own. In fact, adapted science took place in a social studies classroom with no laboratory facility. I either had to wheel-in every lab equipment for the experiments I planned or, if I needed a bunsen burner or a sink, I had to ask the one science teacher whose spare block coincided with my teaching block, if he would be kind enough to let us in. Things had not changed from the time I was in ESL myself. I remember how all my ESL classes were in the basement level of the large building. Perhaps lack of funding for English language learning and for adapted content courses is the underlying issue here. If funding was made available where content and English language arts teachers could be able to fit sufficient time into their teaching schedules to meet and develop adequate resources, most likely collaborative projects would actualize.

What's more, most teachers in adapted settings are either content teachers or English language teachers which means that developing and implementing an integrated curriculum of language and content without interdisciplinary collaborations could be an overwhelming and daunting endeavor. Although my research was not designed to disclose issues of interdisciplinary collaboration and disciplinary status, my reflections on what was required to make this journey successful make it clear that development and implementation of an integrated curriculum in the absence of collegial, interdisciplinary collaborations for today's adapted science teachers become very challenging.

5.4.4 Recommendations for Teacher Training

The question that comes to mind at this point is how concrete and practical pedagogical strategies can be prescribed for professional development workshops, interdisciplinary collaborations and teacher training programs. It is no easy job to 1) encourage student participation- not only of one or two confident students but of all of those who may have feelings of hesitation, 2) weave the learners' knowledge into the talk of the lesson for validation, 3) introduce the disciplinary perspectives by reducing the learning demands, 4) orient the students with field-specific vocabulary, the key language functions and discipline-specific registers, and 5) raise the students' critical knowledge of the two social languages they now speak: their newly acquired school science view and their culturally and linguistically diverse way of talking and thinking. I believe a discussion of TLA is essential to shed light on such expert scaffolding and pedagogical strategies without burning out teachers who are already overworked and underpaid. When interdisciplinary collaborations become a challenge, both language and content teachers need to acquire pedagogical skills in both domains to effectively teach their pupils. In other words, raising the content awareness of language teachers and the language awareness of content teachers is a feasible way forward in preparing teachers in CBI-related settings (Andrews & Lin, 2017; Lin, 2016; Wu & Lin, 2019).

Furthermore, dialogic discourses, found to promote learning gains in the literature and in my data analysis, place heavy demands on teachers. In a dialogic and interactive classroom talk, the teacher not only needs to teach the subject matter concepts but also anticipate and consider students' ways of thinking and talking, and the language features necessary in expressing meaning making according to the disciplinary norms. It is not just the question of knowing some science but also to have insight into the kinds of strategies and language accommodations to move along the process of meaning making. According to Scott et al. (2006), employing dialogic interactions cannot always be mapped out in advance by the teacher since "the direction of development of lessons must be consequent upon (for the responsive teacher at least) the interest and concerns of the students" (p. 623). The teachers need to skillfully, expertly and often spontaneously revise their lessons, activities and pedagogical strategies to ensure that discourse engages students dialogically. Hence, the discussion of TLA becomes essential again, both for integrating teaching of language and content, and for inviting dialogicity in the classroom discourse. Below is my list of pedagogical implications for TLA in adapted teaching based on the findings of the current research:

- Teachers need to have TLA to *purposefully* navigate the shift between dialogic and authoritative discourses to the benefit of the students. Lack of TLA restricts teachers' ability to engage in dialogicity and compels them to resort to lecture style or authoritative communication only.

- Teachers need to have TLA to probe and activate ELLs' disciplinary background knowledge as well as their gaps in knowledge. There is much benefit in highlighting what students know as well as what they don't know.

- Teachers need to have TLA to carefully design lesson objectives in advance which address both content and language gains.

- Teachers need content and language awareness to create an ongoing written dialogue in the form of a journal as an outlet which the less vocal students can utilize. Teachers can comment on language structures and offer formative assessment on students' conceptual gains and encourage them to adopt an active voice on controversial science topics by developing complex argument structures and critical reasoning skills.

- Teachers need to account for content in planning so when learning demands are larger, they choose a communicative approach to appropriately scaffold and identify knowledge gaps and misconceptions.

- Teachers need knowledge to expose students to differentiated speech forms and support their use of them in developing scientific understanding.

- Teachers need impromptu and expert skills in recognizing the learners' linguistic demands and gaps in knowledge.

- Teachers need to raise their TLA to allow for problematization of content, students' agentive participation and to provide relevant and interesting resources and materials. These practices will allow the learners to be recognized as possessing scientific authority.

- Teachers need to have TLA to structure debate lessons along the course of a unit so that students engage in the same kinds of intellectual work that scientists engage in as they attempt to develop new knowledge inside the classroom. This way students can build their knowledge-based reasoning skills so that an end of the term debate grounds students' reasons and evaluations in knowledge and invites all voices- not just the voices of the confident students.

There is little consensus on how to support teachers to develop instructional strategies in CBI (Von Esch & Kavanagh, 2017). However, I believe the above guidelines are the basic essential steps in starting the conversation about the kinds of teacher knowledge required for teachers in adapted settings. Both content area teachers or English language arts teachers assigned to adapt their curriculum to cater to ELLs in content courses, will benefit from understanding and acquiring this knowledge base.

5.4.5 Concluding Thoughts

Curricula falling short of offering rigorous content will make fewer cognitive demands and leave out more academic genres and registers required in college, which will in turn translate into low-track preparatory classrooms marginalizing ELL students (Bunch, 2013; Leki, et al. , 2008; Lin, 2016; Walqui & van Lier, 2010). I believe my research analyses have greater implications as they offer examples of language and content integration in practice and could support CBI teachers, who face constraints and challenges in keeping content rigorous while skillfully and explicitly teaching language in context. Pre-service teacher training programs can benefit from the recommendations of this research in terms of identifying the types of knowledge required of teachers in adapted settings. As well, in-service teachers can gain insights exploring the pedagogical inquiries and tensioned dichotomies of discourse a teacher must navigate within to provide the foundations of social-emotional competency-building to the learners. Furthermore, as pedagogical goals dictate and adjust the language of interaction in the classroom (Sato et al., 2017; Seedhouse, 2004; Walsh, 2003), political agendas and epistemological beliefs behind curriculum design invariably play themselves out in pedagogy. Therefore, this classroom research aimed to shed light on how a teacher's development of content and language awareness in meaningful ways could facilitate the learning outcomes of the students (Andrews & Lin, 2017) where they displayed science literacy as well as knowledge-based critical reasoning skills. This is why the social discourse of a science classroom through inquiry-driven pedagogy needs to extend itself to teaching the genre of debate, knowledge-based arguments (or ADI) and reasoning as well as reading between the lines in order to create the capacity for building conditions which manifest into full and equitable social participation for ELLs.

In educational research, it is pertinent to investigate what pedagogical and epistemological teacher beliefs can maximize students' potential to build competencies towards greater social empowerment in their futures. My research lent itself to investigations of the relationship between learning in the academic domain and becoming more competent in the affective domain. I was able to offer data to shed light on this interwoven phenomenon in the discursive interactions of two classroom debates. Both the dialogic and authoritative ends of the discourse domain played key roles in manifesting success in students' "argumentative competency" and in turn a sense of "scientific citizenship". Science debates which address controversial topics of urgent environmental and climate crises convey to the learner's relevance and significance to their own well-being and their participation in future work or educational endeavours. Yet, more research is needed to do a fine-grain analysis of the nuances of science practices and discussions which can lead to successful debates, as well as how all and not just a talkative few can be engaged in whole-class discussions. We also need more knowledge of the mechanisms that serve as a bridge from discussion and debate within a group context to developing and internalizing individual capabilities with the subject matter (Duschl & Osborne, 2002). This teacher knowledge is crucial to be able to question and refine instructional practices and do all that we can so that the persistent inequities in science classrooms that prevent ELL students from reaching their full potential are identified and erased.

In the design and delivery of my research with the aim to diminish the inequities ELL students face in science classrooms, I created curriculum for two units based on the BC Ministry's prescribed learning outcomes for grade 10 science. I did not leave out, shorten or simplify any of the mandated outcomes. I ensured that the students were provided with the same content, laboratory and multi-media resources as students in regular science 10. Also, it was important to ensure that the students were offered equal access to these resources by means of instructional scaffolding and language support. Furthermore, in the communicative approach where discursive interactions offer as much information-giving as they do information-seeking, I made certain that the students' perspectives, ideas, and prior knowledge were inquired upon and woven into the talk of the lesson. In doing so, the students saw their ideas acknowledged, their opinions considered and their suggestions forming the backbone of the teacher's answers. Indirectly, the validation of their knowledge helped construct the building blocks of social-emotional competencies which reflect my overarching goal in conducting this project. The title of my dissertation is "The Power of Discourse in High School Adapted Science with English Language Learning Students", and I have attempted to paint a picture of the discourse of classroom interactions as spaces for teaching the pragmatics and the semantics of science as well as the art of reasoning and argumentation, in the intersection of language and content. I see this approach to pedagogy as efforts to prepare ELL students to participate in society, gain membership and demand rights and privileges.

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