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Author(s)	Tagnin, Laura
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Science Classroom Discourse and Learning in Secondary Biology Classrooms Implementing a Content and Language Integrated Learning (CLIL) Approach

by

Laura Tagnin

A thesis submitted for the degree of Doctor of Philosophy
to the School of Education, National University of Ireland, Galway

Supervisors:

Dr. Manuela Heinz

School of Education, National University of Ireland, Galway

and

Dr. Máire Ní Ríordáin

School of Education, University College Cork

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DECLARATION

I, Laura Tagnin, certify that this thesis is all my own work and that I have not obtained a degree in this University or elsewhere on the basis of any of this work. Where use has been made of the work of other people it has been fully acknowledged and fully referenced.

Signed: ______________________________

Date: ______________________________

ABSTRACT

This multiple case study research analyses upper secondary teachers' and students' experiences of learning biology through the medium of a foreign language, which in this study is English, in the European context (German and Italy). This instructional approach has been named Content and Language Integrated Learning (CLIL).

So far, the focus of research into CLIL has been mainly on language. When looking at content (science, in this study) research into CLIL has tended to adopt a language learning orientation in design, analytical tools and theoretical orientation. Furthermore, findings on content learning are overall inconclusive. Specifically, when examining science learning, research results are extremely scarce and often published in languages other than English. Leading on from this, the aim of this study is to contribute to the science teaching practice by filling the evidenced gap with a deeper understanding of science learning when a CLIL approach is implemented.

Three case studies (two in Germany and one in Italy), where investigated through a sociocultural perspective of learning, by using mixed methods. The qualitative element, which is dominant in this study, explored discourse practices and teachers' beliefs by analysing audio-recordings and observational data. The quantitative aspect incorporated a student questionnaire to examine students' perceptions about learning science through a CLIL approach. Central to this study is the analysis and discussion of how opportunities for learning science are promoted by classroom discourse.

Findings demonstrate that students' cognitive engagement is inseparable from linguistic production. Teaching strategies that promote the building of science include contingent questioning, a hybrid discourse, translanguaging practices, metadiscourse and linguistic redundancy. Teachers' beliefs about language appear to effect learning environments and classroom practices. The major contribution of this study is its insight into how to develop language resources and implement teaching support measures and discourse practices that will enhance science learning.

To Alessandro, my friend, my love, my life.

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LIST OF ABBREVIATIONS AND ACRONYMS

AL = Academic Language

BICS = Basic Interpersonal Communication Skills

CALP = Cognitive Academic Language Proficiency

CBI = Content Based Instruction

CBLT = Content-Based Language Teaching

CLIL = Content and language Integrated Learning

CLT = Communicative Language Teaching

CoP = Community of Practice

CUP = Common Underlying Proficiency

EAP = English for Academic Purposes

ELL = English Language Learner, usually enrolled in ESL classes (plural ELLs).

EFL = English as a Foreign Language. Term used when students are studying English in non-English-speaking countries.

ESL = English as a Second Language. Term used when students are studying English as non-native speakers in a country where English is spoken. The term ESL may be more inclusive and includes EFL.

FL = Foreign Language

HOT skills = Higher-Order Thinking skills

IB = International Baccalaureate

ICL = Integrating Content and Language

L1 = "Language 1" = an individual's native language, also home language

L2 = "Language 2" = the language being learned or studied, sometimes referred to as foreign language, depending on the context

LEP = 'Limited English Proficient' students, usually in bilingual immersion programmes or transitional bilingual education programmes.

LOT skills = Lower-Order-Thinking skills

NOS = Nature of Science

OTL = Opportunity to Learn

SLA = Second Language Acquisition

TA = Thematic Analysis

TBE = Transitional Bilingual Education. Transitory period (usually up to 3 years) of bilingual education for minority-language students of immigrant background before moving to mainstream all-English classes.

ZPD = Zone of Proximal Development

Chapter 1 Introduction

1.1 Introduction

Since its introduction in the 1990s, the pedagogical approach called Content and Language Integrated Learning, or CLIL, has been rapidly spreading all over Europe, where it was first conceived. CLIL consists of the teaching of a non-linguistic subject through the medium of a foreign language both at primary and/or secondary level of education. To date, CLIL is a general term that does not designate a specific or uniform pedagogy (Czura, Papaja and Papaja, 2013). In addition to foreign languages, also regional, minority or other state languages are widely used for CLIL provision (European Commission/EACEA/Eurydice, 2017). Interestingly, since it first entered the European scene, CLIL encountered the blind favour of many parties. Most scholars praised CLIL for two decades without solid empirical research to back them up (Pérez Cañado, 2018). Many educators have seen CLIL as a catalyst for didactic innovation (Marsh, Maljers and Hartiala, 2001). Many families have seen CLIL as a ticket for the internationalization of education (Van de Craen and Surmont, 2017). In addition, CLIL has been on the European political agenda because of the increasing prioritization of bilingual education in the European Union (Pérez-Vidal, 2013). Overall, CLIL has been so attractive because it serves many agendas. However, many researchers have begun to acknowledge the need for a deeper understanding of the "discrepancies between educational policies and real teaching contexts" (Cabezas Cabello, 2010, p. 86).

As the literature review of this research progressed it became evident that little is known about how specific content areas are affected by CLIL instruction. One of these areas is science given it is a common subject taught through this approach (European Commission/EACEA/Eurydice, 2017). But science learning is already "akin to learning a foreign language and require[s] the student to learn the grammar and semantic meaning associated with its forms of expression" (Wellington and Osborne, 2001, p. 65). Not only this, but also "[n]o one would dream of teaching a foreign language without giving pupils the opportunity to talk and use the language" (Wellington and Osborne, 2001, p. 83). Accordingly, teaching science through a CLIL approach means dealing with at least two language-related challenges: the foreign language as a medium of instruction and the science language. Little is known about how science learning is effected and affected by such an instructional context as only few studies exist that investigated this particular learning milieu (e.g. Bonnet, 2004; Kircher, 2004; Koch and Bünder, 2006).

This doctoral study is focused on bilingual education and science education in the European context (German and Italian) and analyses upper secondary teachers' and students' experiences of learning science through the medium of a foreign language (English). This includes examining classroom discourse practices and interactions, teachers' beliefs and students' perceptions, and, in the process, developing significant insights into pedagogical influences of CLIL on science learning.

This doctoral study is designed to build on research undertaken in other cultural and social contexts—such as with minority-language learners—while suggesting some productive lines for further enquiry. Although being a European phenomenon (but it is spreading beyond Europe), CLIL is also culturally dependant on the setting in which it is taking place (Nikula, 2017a). Thus, it was necessary to undertake a study that could capture the situated nature of this educational phenomenon, but that could also produce findings relevant to a wider audience. Such research makes a significant contribution to the domain of science education concerned with bilingual education at an international level. It also contributes to CLIL practice at a European level.

1.2 Background to the Research

The rational of Content and Language Integrated learning, or CLIL, from its start in 1994, has been to enhance language learning through the "teaching of classes in a foreign language for disciplines other than languages" (Council of the European Union, 1995, A-2). Since then, CLIL has been referred to as having "a major contribution to make to the [European] Union's language learning goals" (European Commission, 2003, p. 8). One of the reasons often provided as support for CLIL is the belief that students are learning two curricular subjects simultaneously: a foreign language and a non-linguistic discipline taught through the target language (Lasagabaster and Sierra, 2010). Apparently, CLIL saves time, because "two things can be learnt in the slot otherwise taken up by one" (Dalton-Puffer and Smit, 2007, p. 9). Since its introduction, CLIL has raised high expectations in both research and practice and has spread at a rapid pace. It is difficult to say how many (science) teachers and students have been so far involved in CLIL programmes, as data from the different European countries are very fragmented and difficult to compare. The most recent report issued by the European Commission/EACEA/Eurydice (2017, pp. 55-58) states that nearly all

European countries have schools providing CLIL instruction but that only a few have adopted this approach in all schools at some stage. These include Austria and Liechtenstein at primary level, and Italy, where CLIL is provided in the last grade of upper secondary level. In the other countries, CLIL is never compulsory and it is usually provided on the basis of a varied range of admission criteria.

Originally, the idea of bringing content learning into the mix of language learning was guided by the assumption that an authentic and strong focus on a disciplinary matter makes the language learning environment cognitively more engaging, more authentic and motivating (Smith and Patterson, 1998) and therefore more successful. To guarantee the authenticity of the content it was decided that content teachers were primarily responsible for teaching in these programmes. This decision did not sit well with many language teachers and linguistics scholars who did not fully trust “the tacit assumption that there will be incidental language gains” (Dalton-Puffer, 2007, p. 295). By contrast, the community of content teachers was divided between those who embraced the CLIL approach as a way to renew and enhance their teaching practice (Infante, Benvenuto and Lastrucci, 2013), those who developed a sense of uncertainty about how to cope with the new challenges brought by CLIL to their teaching (Moate, 2011); and those who developed a downright aversion to CLIL because they feared negative influences on the students’ subject matter competences (Breidbach and Viebrock, 2012; Haagen-Schützenhöfer, Mathelitsch and Hopf, 2011). In academia, linguists entered into a heated debate (e.g. Bruton, 2013, 2015, 2017; Cenoz, Genesee and Gorter, 2014; Hüttner and Smit, 2014; Pérez Cañado María, 2017; Pérez Cañado, 2016b; Pérez Cañado, 2018) and engaged in a prolific evidenced-based research about the effects of CLIL on language learning in particular (e.g. Bredenbröker, 2002; Coyle, 2013; Dalton-Puffer, Faistauer and Vetter, 2011; Nikula, 2007, 2010; Smit and Dalton-Puffer, 2007; Vallbona González, 2014). In the meanwhile, the academic communities representing and researching the different disciplinary subjects and interested in CLIL did not react (at first) and accumulated a delay on specifically informing and supporting disciplinary teaching within CLIL settings. This delay created a lack of evidence-based research concerning content instruction in CLIL settings (Paran, 2013), leaving practitioners without practical guidance and stakeholders with high expectations at risk of being unfulfilled (Bonnet and Dalton-Puffer, 2013).

At present, only few studies exist on content learning in CLIL settings that are grounded in the theoretical frameworks of the discipline they research, and utilise methodological tools that are typical of the research area of the subject matter they refer to. Examples are the works by Bonnet (2004) in Chemistry education, Kircher (2004) in Science education, Ní Ríordáin (2008) in Mathematics education and Heine (2010) in Geography (with a focus on problem-solving). These studies are rarely branded as CLIL studies (for instance, in Germany the acronym CLIL is nearly always replaced by “bilingual education” or “bilingual lesson”) and are not always written in the English language, meaning that their reach is sometimes limited. However, they offer valuable insights into how specific content learning is effected by CLIL approaches.

Although science education research has so far neglected CLIL settings (see Bonnet, 2004; Heine, 2010; Ní Ríordáin, 2008), it would not be fair to say that science education research has not considered the emerging needs of language sensitive classrooms. In response to the growing movements of people who migrate from one country to another, most Western school systems are challenged by classrooms which are becoming progressively more diverse, both culturally and linguistically (Rosenthal, 1996). As a result, a significant amount of research concerned with minority-language students has been produced (reviewed by Lee, 2005). In the meanwhile, new science curricula have been evolving (e.g. NGSS Lead States, 2013) and a growing emphasis on discourse practices—such as articulating, discussing and defending ideas—to support science inquiry and content understanding is emerging (cf. Lee, Quinn and Valdes, 2013). This new trend is placing a high linguistic demand in particular on English language learners (Buxton and Lee, 2014). Some research projects are specifically concerned with trying to integrate these new challenges of science literacy with the needs of minority-language learners (Brown, 2006; Brown and Spang, 2008; Buxton, Allexsaht-Snider and Rivera, 2013). Even though these learners are different from typical CLIL learners (who usually belong to dominant-language groups), some practices and approaches that have produced good results with minority-language students could be exported to CLIL environments. One of the approaches I see as particularly relevant is the orientation of language-as-resource (Ruíz, 1984), which is discussed and investigated in this study.

1.3 Scope and Significance of the Study

Science teachers who are implementing a CLIL approach, or who would like to start adopting it, are facing important challenges. On the one hand, there is a need to involve students in discourse practices to support both conceptual understanding and the development of science language for asking questions, defining problems and engaging in argument from evidence (Cheuk, 2013). On the other hand, there are language-related issues about using a foreign language as the medium of instruction (i.e. the CLIL approach) without proper guidance as to how this might be best done. As a result, after an initial phase of enthusiasm about CLIL, many content teachers begin to develop more critical attitudes including fear that content learning may be slowed down by CLIL (Cinganotto, 2016). Similarly, science teachers who have always mistrusted CLIL, are finding their sceptical attitude even more justified (Haagen-Schützenhöfer *et al.*, 2011). As CLIL may truly represent a way to promote plurilingualism (Marsh *et al.*, 2001), it is important to produce evidence-based research that empirically demonstrates how content teaching, and science teaching in particular, can be supported and promoted by a CLIL approach. In light of the emphasis placed on language and on communication by educational research in general (Cazden and Beck, 2003) and by science educational research in particular (Lemke, 1990; Roth and Lawless, 2002), there is an urgent need for a deeper understanding of the impact of science classroom discourse on science learning when a CLIL approach is implemented, which is the main aim of this study.

In particular, this study intends to deviate from mainstream research about CLIL and to position itself in the niche of science education research focused on language and on a communicative approach to learning. This study follows and builds on the tradition of previous studies in science education in CLIL settings (such as Bonnet, 2004; Kircher, 2004) by adopting an original theoretical framework combining sociocultural theories applied to science education, bilingual education theories and an orientation of language-as-resource.

The research is concerned with exploring how opportunities for learning science are promoted in biology classrooms at upper secondary level when a CLIL approach is implemented. In the international field of science education, this research makes a significant contribution to our understanding of how science learning is interactionally and situationally constituted and made visible in bilingual classrooms. For instance, many aspects of this study examining science classroom discourse (e.g. the use of questioning and metadiscourse for promoting conceptual understanding, the use of translanguaging practices, the teaching of the nature and of the practices of science) have not yet been investigated in bilingual/CLIL settings. In addition, this study also makes a significant contribution to the international debate on CLIL, as it offers an alternative perspective by examining science learning processes in CLIL settings.

1.4 Personal and Professional Stance

My interest in science learning when a CLIL approach is adopted arises from over ten years of classroom teaching experience in the Italian upper-secondary school system as a biology teacher, in particular, my more recent experience of teaching science through the medium of English to Italian students. This experience has illustrated for me how a new approach to teaching in a more challenging environment can disrupt well established habits and stimulate personal reflection and questioning.

I appreciate the many ways in which the CLIL approach changes teaching practices and the opportunities it offers students for developing bilingual attitudes. However, what has resonated with me is the impoverishment of curriculum that potentially threatens science learning and deep learning for the sake of language learning, making any knowledge acquired without understanding very fragile. And it is not only an issue of understanding. It is also a problem of going sufficiently deep into the curriculum to find ways to arouse interest, to inspire students with science and to help them embrace the culture of doubt. Because what I have found when teaching and learning science in a foreign language is that it becomes extremely difficult to go deep. Unfortunately, no training about CLIL that I have ever received has assisted me to overcome these difficulties. Also, in my teacher training, I have been taught that my job as a CLIL teacher is to facilitate and not to simplify, but my experience led me to think that the line between the two approaches is less obvious than it seems.

After attending a few specific training courses and interrogating existing literature, I soon realised that many of the problems I experienced in teaching science through a CLIL approach had not been addressed yet. Hence, a research project developed from my own questions and with the aim of generating a deeper understanding of science learning in CLIL settings that could enhance teaching practice.

1.5 Research Problem, Research Focus and Aims of the Research

The research problem is to investigate opportunities for learning science, with a focus on discourse practices at upper secondary level when a CLIL approach is implemented.

In this study, opportunities for learning science are conceived as an interactional phenomenon, framed within a sociocultural perspective of learning that posits that learning originates in social interactions (Vygotsky, 1978). Within this framework, an opportunity for learning is an opportunity that exposes the students to science content and that gives them a chance to collaboratively interact with such content and make sense of it. As the focus of the study is on discourse practices, learning opportunities also require that students articulate their thinking by developing and using the discipline-specific language.

The primary aims of this research study are:

- to examine how discourse practices facilitate opportunities for learning science when a CLIL approach is adopted at upper secondary level;
- to investigate the perspectives of teachers and students about the phenomenon of learning science through a CLIL approach at upper secondary level.

1.6 Research Questions

The whole research process and each research component of this study are guided and influenced by the research questions. The overarching research question emerging from the research problem is:

How is science learning supported by classroom discourse when a CLIL approach is implemented in three case studies involving German and Italian upper secondary level science classrooms?

In addition to this main research question, four sub-research questions emerged:

1. What interactional discourse practices promote opportunities for learning science when a CLIL approach is implemented at upper secondary level? (RQ1)
2. What teaching discourse practices promote opportunities for learning science when a CLIL approach is adopted at upper secondary level? (RQ2)
3. What are teachers' goals and epistemological beliefs about teaching science through a CLIL approach and how do they affect classroom practice? (RQ3)
4. What are upper secondary level students' perceptions of learning science through a CLIL approach? (RQ4)

The first two questions (RQ1 and RQ2) might be considered as a subset of the overarching research question addressing how discourse practices facilitate opportunities for learning science, while the remaining two (RQ3 and RQ4) are intended to capture the two different perspectives in this study, namely, the teacher participants (in terms of goals and epistemological beliefs) and the student participants (in terms of perceptions).

1.7 Study Description

Because this study explores the complexities of real-life classrooms through a situated/sociocultural lens to learning, a multiple-case study design was adopted

(Stake, 2013; Yin, 2009). This design is suitable for both yielding rich data and for attempting some cautious generalizations (Merriam, 1997). In addition, data were collected and analysed using a mixed methods approach. This is particularly suitable for collecting multiple participants' perspectives (Greene, Caracelli and Graham, 1989). A graphic summary of the paradigm, approaches and methodology implemented is represented in Figure 1.1.

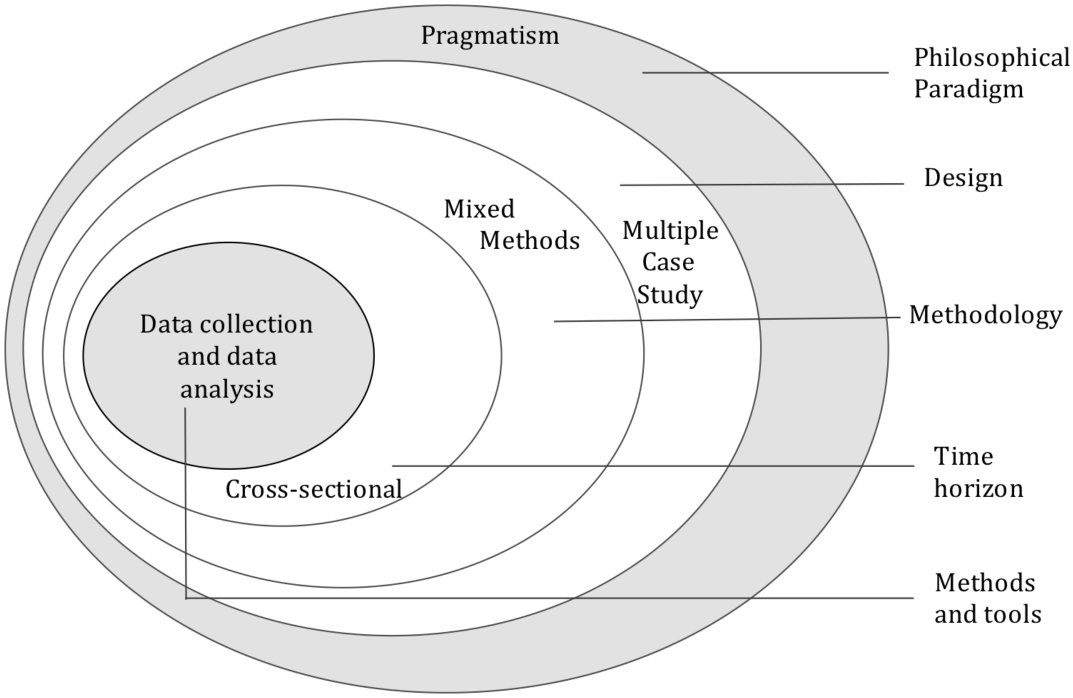

Figure 1.1 The "research onion" for this research study. Adapted from Saunders, Lewis and Thornhill (2011, p. 138)

Three case studies were selected and examined as the object of this study. These consisted of three schools (two in Germany and one in Italy), represented each by a science teacher and his or her three or four classes of upper secondary students. The research questions guided the data collection. In particular, for each research question, specific data collection strategies and tools were designed and implemented, which involved:

- *direct observations of lessons with relative field notes:* a total of 34 class periods of 50 minutes' duration each on different topics of biology were observed and field notes taken using a semi-structured observation schedule;
- *the audio-recording of classroom discourse*: the classroom discourse of 34 class periods was transcribed verbatim;
- *a questionnaire distributed to the students* examining their perceptions of science/CLIL (n = 160 questionnaires were collected);
- *an individual follow-up interview with each science teacher* (n = 3).

Classroom audio-recordings were transcribed and analysed using both a discourse analysis focused on classroom interactions (influenced by Mercer, 2004) and an interpretive thematic analysis (Braun and Clarke, 2006). The semi-structured teacher interviews were transcribed and analysed using thematic analysis. A descriptive statistical analysis of frequencies was employed for analysing the questionnaire responses. Overall, data were analysed and interpreted across the whole data set, across case studies and within case studies (Mills, Durepos and Wiebe, 2010, pp. 582-583). Findings from different sources of data were integrated, jointly interpreted and finally presented with ample provision of examples (Creswell and Clark, 2011).

1.8 Limitations of Study

The author recognises that this research study is affected by a number of limitations. These include:

- Samples were purposively self-selected (as opposed to randomly) to maximise the insight into the investigated phenomenon. As a result, information-rich samples were examined, and rich findings were obtained. However, these findings are not suitable for drawing broad generalizations.
- Although some relationships between variables emerged, both sample size and methodology are inadequate for drawing causality inferences.
- Although some patterns emerged from the student questionnaires, the total student sample is too small to draw broad generalizations.
- The number of observed and audio-recorded class periods and teacher interviews in this study is relatively small for drawing generalizable conclusions about science learning in CLIL settings at upper secondary level of instruction.

Overall, it appears that the small size of the study which does not allow for broad generalisations is the main limitation of this research project. However, the researcher considers the findings present a good description of science learning in CLIL settings, a research area that has been under-researched to date. In addition, some key findings are corroborated by data from different sources (e.g. observations, transcripts, interviews, questionnaires), which make the picture they depict richer and more informative (Torrance, 2012).

Further details of the limitations of this study are discussed in section 4.22 following a detailed account of the methodology employed in this study.

1.9 Structure of Thesis

In this section, the outline for this thesis is presented, with a summary of each chapter included. The chapters in this thesis are as follows:

Chapter 1 – Introduction: The doctoral study is introduced. The significance and aims of the study are described in relation to its cultural and educational background. Research questions are outlined. A brief introductory description of the research methodology employed in the study is provided and the main limitations of the study are stated.

Chapter 2 – Bilingual Education: The chapter reviews the current literature on bilingual education with a closer look at the CLIL approach. The main features and approaches to bilingual education and the most relevant cognitive theories relating to this study are explored. The CLIL approach is presented and contextualized within both the bigger picture of bilingual education and the local dimensions of the countries where the fieldwork of this study was undertaken. How CLIL affects content learning in general, and science learning in particular, is examined. However, a lack of studies in this specific research area is emerging. The chapter concludes by highlighting that very little is known about how the development of science content, science epistemologies and science values are promoted and facilitated thorough discourse in the CLIL science classroom.

Chapter 3 - Science Education with a Focus on Language: The chapter highlights how science education is evolving and how an emerging emphasis has been placed on the teaching of the Nature of Science, on classroom language and on the participatory nature of the building of science knowledge. A further exploration of the role of language in the science classroom is conducted with a focus on classroom discourse. In particular, classroom discourse is unpacked for explaining how it functions to promote knowledge building. In relation to bilingual/CLIL education, some specific knowledge gaps in our understanding of science discourse practices are identified. Subsequently, the theoretical framework adopted in this study is outlined. In particular, how this study draws upon a sociocultural approach applied to science education with a focus on language and on discursive practices employed for promoting participatory learning, is explained. In addition, the research study is informed by cognitive theories of bilingual education and is consistent with an orientation of language-as-resource. Finally, the construct of opportunities for learning science is presented and examined in relation to the purposes of this research study.

Chapter 4 – Methodology: The chapter provides a detailed description of the research design and methodologies employed in the study. Throughout the chapter, both research questions and the theoretical framework are linked to methodological choices. Research instruments and data collection methods are explained for both the qualitative and quantitative components. Data analysis is discussed including ethical issues concerning validity, reliability and triangulation. Limitations of the study are outlined.

Chapter 5 - Building Science through Classroom Discourse: The main focus of this chapter is on the findings from the analysis of whole-class classroom interactions, which are presented and concurrently discussed. In parallel, findings from the student questionnaires and the teacher interviews are presented and integrated with observational data so as to find patterns and relationships. The chapter delves further into how opportunities for learning science arise and are made visible through discourse practices both in terms of conceptual understanding and science language development.

Chapter 6 – Making Science Accessible: The main focus of the chapter is on teachers' practices that promote and facilitate science learning. It examines and unpacks classroom discourse through a thematic analytical approach with the purpose of understanding how science content, science values and science epistemologies are dialogically promoted in the CLIL upper secondary science classroom. Similar to Chapter 5, findings from the analysis of discourse are integrated with findings obtained from teacher interviews and student questionnaires responses. Throughout the chapter, findings are presented with a relevant selection of transcript extracts and discussed in relation to relevant literature.

Chapter 7 - Conclusions: The chapter concludes the thesis by summarising the conclusions of the study, making recommendations and putting forward suggestions for future research based on the findings of the investigation.

1.10 Conclusions

The chapter presents the rationale for conducting this research project. It identifies the scope, aims and research questions while also providing an insight into the author's motivations for the research project. It describes the background to the research from both a European CLIL research perspective and an international science education perspective and identifies the knowledge gap in terms of the effects of a CLIL approach on science learning. The need for such research was made clear both in the European CLIL education context and in the international science education research domain concerned with bilingualism. The theoretical constructs that frame the study are introduced and the research methodology outlined, while acknowledging the main limitations that affect the research study. Chapter 2 proceeds to examining in greater detail the relevant background literature by examining bilingual education in general and CLIL in particular as well as reviewing key concerns in science education when impacted by bilingual learning environments.

Chapter 2 Exploring Bilingual Education and CLIL

One language sets you in a corridor for life. Two languages open every door along the way.

Frank Smith

2.1 Introduction

As the general aim of this study is to contribute to the science teaching practice with a deeper understanding of science learning when a CLIL approach is implemented, a close look at both science education and CLIL/bilingual literature bodies is necessary. In particular, the aims of this literature review are:

a) to make explicit the literature gap to which this study is directed;

b) to identify key issues in the two main research areas and develop a cultural, historical and conceptual understanding of science education in bilingual settings;

c) to develop a theoretical framework that helps design an appropriate methodology and guides how the analysis is conducted and conclusions are drawn;

d) to justify the conclusions as contributing to knowledge.

The present literature review is organized thematically rather than chronologically. However, time progression will still be an important factor in analysing the development of concepts and theories. As this study mainly draws upon two literature bodies, these will be separately analysed in two chapters (2 and 3). The present chapter reviews the first literature body, namely the existing research on bilingual education with a close look at the widespread approach known by its acronym CLIL, or Content and Language Integrated Learning. The second corpus of literature is concerned with science education. This second literature body is examined in Chapter 3. Finally, at the end of Chapter 3, the two bodies of literature are brought together in order to develop the theoretical framework of this research study.

This first chapter of this literature review opens by presenting and analysing bilingual education, as this particular kind of education can inform science learning processes when the language of instruction is not the first language of the students. In order to understand how and the extent to which science learning is affected by the use of a foreign language, existing cognitive theories of bilingualism developed to explain language proficiency are reviewed and analysed. What linguistic challenges bilinguals face in school environments and how their linguistic resources can be harnessed is also examined. Subsequently, the CLIL approach is presented and contextualized into the perspectives of bilingual education and of science education. The chapter ends by identifying a significant knowledge gap that this study may contribute to filling.

2.2 Cognitive Theories of Bilingualism

Before examining bilingual education, a very brief introduction to bilingualism and its cognitive theories is provided here. As CLIL learners are considered to be bilingual learners, how they cognitively access knowledge in content instruction is relevant in this study. Most of the research into bilingualism and bilingual education deals with the notion of *second language*, or L2, to differentiate it from *first language*, or L1. Because this study deals with CLIL, which is a particular kind of bilingual education, the term *foreign language*, will be preferred to *second language*, because it is closer to what CLIL is actually about (in most of the cases). However, because of the prevalence in the literature of the term *second language*, these two terms will be used interchangeably for the purpose of this review.

Simply put, bilingualism can be defined as "the use of at least two languages either by a group of speakers or by an individual" (Moradi, 2014, p. 147). Bilingualism can be interpreted along a continuum between monolingualism and balanced bilingualism, meaning the condition of an individual who is equally fluent in both languages, which is an exception to the rule of the more common unbalanced bilingualism (Beardsmore, 1986; Nortier, 2008). This description of bilingualism is very reductive, because bilingualism is also a "social construct" that cannot be defined outside its context and its people (Heller, 2008, p. 249). However, it would be beyond the scope of this review to further analyse bilingualism in this direction.

Although bilingualism is—today as in the past—the norm for most of the world's population (Kroll, Gerfen and Dussias, 2008), the misconception that being bilingual or undergoing a bilingual education may negatively affect or delay the ability to learn because of an alleged limited storage capacity of our mind persists at many levels. Consequently, bilingual learners would be at a disadvantage when it comes to acquiring new knowledge (May, Hill and Tiakiwai, 2004). This inaccurate idea is termed the Separate Underlying Proficiency (SUP) model. Even if extensive evidence suggests that bilingual education is effective and advantageous, sceptical attitudes towards bilingualism are still common (García, 1991; Mehisto and Genesee, 2015). Questions such as whether second language learning enhances cognitive development and how a second language learning affects the literacy skills in the mother tongue still divide opinions (Bournot-Trites and Tellowitz, 2002). Over the past several decades, improvements in neurolinguistic knowledge have allowed researchers to better understand the cognitive development of children in bilingual educational environments (Jasińska and Petitto, 2014). However, in research conducted so far, nothing indicates that the bilingual brain has a limited capacity or that bilingual language development produces language delays (Buchweitz and Prat, 2013).

Nearly four decades ago, Jim Cummins (1980) challenged the SUP model with his Common Underlying Proficiency (CUP) model. According to Cummins' model there are not separate reservoirs for each language. Not only is there evidence that the human brain does not run out of space, but it is also possible to transfer knowledge, literacy and metacognitive skills from one language to another, and both languages benefit from and build upon each other (Baker and Prys Jones, 1998). Genesee, Lindholm-Leary, Saunders and Christian (2006, p. 83) refer this model as a "reservoir of abilities" supported by "parallel abilities across languages." This idea is illustrated by Cummins (1984a, p. 143) with the analogy of two integrated icebergs with a submerged underlying common core, i.e. the Common Underling Proficiency and two emerging surface features, one for each language (see Figure 2.1).

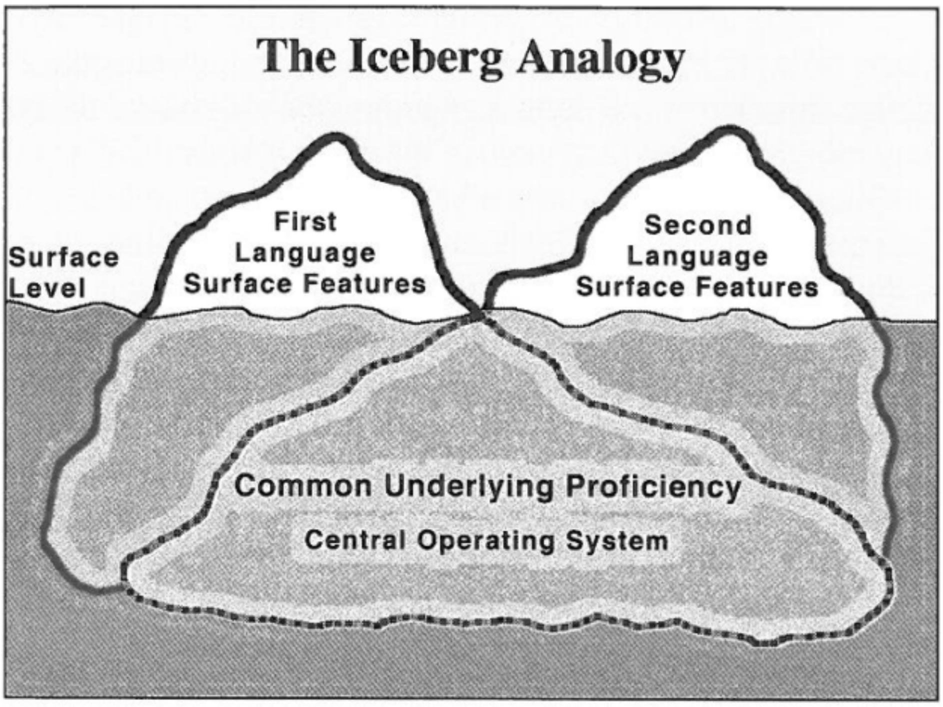

Figure 2.1 The Iceberg Analogy, from Baker & Prys Jones, 1998, p. 82, adapted from Cummins.

According to this model, regardless of the language that a bilingual or multilingual person is using, the thoughts are processed by the same central operating system and a transfer between languages is possible. In other words, abilities that have been acquired in L1 context are accessible for L2 usage as well and vice versa. In addition, the greater the level of language and academic proficiency in L1, the stronger the transfer of these proficiencies to L1. This model of transfer of knowledge and skills explains, at least in part, the positive results of an early but highly influential study conducted by Peal and Lambert (1962). In this large-scale investigation, bilingual Canadian children (French-English) were superior to monolingual French children both in verbal and non-verbal cognitive tests "involving concept-formation or symbolic reflexivity" (Peal and Lambert, 1962, p. 14). Similar results were confirmed in further studies (e.g. in Baker and Prys Jones, 1998; Hakuta and Diaz, 1985). Also, Cummins' CUP model underpins the *developmental interdependence hypothesis* (Cummins, 1979) which says that when the use of a rich L1 is promoted in the child's environment outside school, then an intensive exposure to L2 is likely to result in high level of L2 achievement at school, at no cost of L1 proficiency (Cummins, 1979, p. 233).

To sum up, Cummins' CUP model supports the existence of a common proficiency underpinning all languages an individual uses, no matter the level of mastery. This model and the *developmental interdependence hypothesis* (Cummins, 1979) provide a fundamental theoretical grounding for recognising the benefits of bilingualism and of a bilingual education that harnesses a child's linguistic resources. The linguistic resources of bilingual learners are examined in the next section.

2.3 Bilingual Learners and the Language of Schooling

As explained in the previous section, being bilingual only rarely means being perfectly fluent in two (or more) languages (Beardsmore, 1986). Most of the times, bilingual students are not yet fluent in the language of instruction, which means they are learning content by using a language that they are still developing. However, the language skills required in a classroom go way beyond learning the grammar of L2 (Fillmore, 1982). In order to effectively participate in classroom discourse, students need a language that is markedly different from the language used outside school (Fang, Schleppegrell and Cox, 2006). Although any student (bilingual or not) is affected by the language of schooling, or academic language, it is in the field of bilingual education research that this construct has traditionally been more salient (e.g. Gibbons, 1998; Valdes, 2004; Zwiers, O'Hara and Pritchard, 2014). Indeed, the reasoning about academic language started with Cummins' proposed distinction between Basic Interpersonal Communicative Skills (BICS) and Cognitive Academic Language Proficiency

(CALP), which Cummins presented as relevant for L2 learners (Cummins, 1980; Cummins, 1984b, 1999).

BICS refers to the language of everyday informal conversation. This is also what Skutnabb-Kangas and Toukomaa (1976, p. 43) refer to as "linguistic facade", or what Gibbons (1991, p. 3) calls the "playground language". BIC skills develop in everyday contexts and are therefore described as "context embedded" or contextualized (Cummins and Swain, 2014, p. 153). With BICS, communication is also helped by contextual factors such as body gestures, facial expressions and speaker's voice tone. The other language proficiency is CALP, which represents the language needed to develop academic competences. This is the formal classroom language used in textbooks, in testing, writing and argumentation. This proficiency is meant to transmit abstract concepts and is "context reduced" or decontextualized (Cummins and Swain, 2014, p. 153). Whereas BICS proficiency in the second language is generally achieved in 1-2 years (Cummins, 2000), CALP competency in L2 requires a longer process of assimilation, generally of 5-7 years (Collier, 1987; Cummins, 1981a; May *et al.*, 2004). However, it is CALP (not BICS) that determines an individual's success at school. Fortunately, CALP developed in L1 contexts is transferable to L2 provided there is adequate exposure to the second language (Cummins, 1999, 2000; 2008b). Cummins called this property of CALP *linguistic interdependence* and he argues that this transfer of proficiency across languages works two-ways if the conditions are right. This is true even for languages that are dissimilar (e.g., Spanish and Basque; English and Chinese; Dutch and Turkish). The positive relationship that exists between the development of academic skills in first and second languages draws upon the aforementioned concept of Common Underlying Proficiency (CUP), i.e. the common pool that is underlying all languages systems a multilingual has acquired. This transfer of skills and knowledge across languages has crucial implications in bilingual education. For instance, Hakuta's study (1990) provides evidence that basic concepts of literacy and numeracy acquired in the first language can be transferred to a second language.

The construct of academic language is considered the descendant of CALP (Anstrom, DiCerbo, Butler, Katz, Millet and Rivera, 2010) and is defined by Zwiers (2008, p. 20) as the "set of words, grammar, and organisational strategies used to describe complex ideas, higher order thinking processes, and abstract concepts". Despite its frequent use, the term academic language remains complex and sometimes contested (Anstrom *et al.*, 2010). According to a recent review conducted by Molle (2015), scholars seem to agree that (a) academic language refers to the language used in school by learners for building knowledge, (b) academic language development is fundamental for academic success; (c) academic language is a construct that encompasses discourse, grammar/syntax and vocabulary; (d) academic language is content-area-specific and (e) it should be thought as a continuum with everyday language (Molle, 2015, pp.13-14).

Even though there seems to be agreement about the importance of academic language for pursuing academic success, little agreement has been reached on how to best teach it to meet students' learning goals. Basically, there are two possibilities: to teach academic language explicitly—i.e. by focusing on forms and rules—or implicitly, meaning without evoking rules (Andringa, de Glopper and Hacquebord, 2011). Although the importance of form in subject matter education has been recognized, putting too much emphasis on it by the teacher could lead the students to mistaken the form as the substance of instruction and therefore to create an "artificial" learning environment (Pimm, 1994). However, ignoring the explicit teaching of genres, language forms and vocabulary is not an option either, as it would discriminate students who otherwise do not have access to them (Schleppegrell, 2012).

Schleppegrell (2013) provides a partial solution to this problem. She observed students that were not focused on language learning *per se* but on learning school subjects *through* language and found that academic language development is supported by a meaningful use of metalanguage. Metalanguage is, by definition, the explicit referring to language. In linguistics, metalanguage is traditionally defined as the "language used to make statements about statements in another language" (Matthews, 1997, p. 233). However, broader definitions have been proposed, such as the "language used to talk about language" (McArthur, 1996, p. 589). Similarly, Hyland (2017, p. 17) refers to metalanguage as "a resource to talk about and reflect on language itself". Schleppegrell (2013) empirically showed that metalanguage helps students to learn the specific registers of a discipline (i.e. academic language). In particular, metalanguage enables students to develop consciousness about language use in context and to recognize linguistic patterns in texts and discourses and use them appropriately.

In terms of research in CLIL settings, although quite a few studies have been concerned with academic language (e.g. Lorenzo and Rodríguez, 2014; Vollmer, 2008), the focus of these studies has been mostly on linguistic aspects. Some studies have investigated academic language in generic CLIL contexts from the perspective of functional linguistics (e.g. Dalton-Puffer, 2007; Llinares, Morton and Whittaker, 2012), and there are also academic publications intended to support the teaching of academic language in CLIL settings with practical advice (e.g. Lin, 2010; Lin, 2016). However, apart from the overall observation that academic language remains "implicit or even secret knowledge on the part of subject teachers" (Vollmer, 2008, p. 249), little is known about how the development of academic language is empirically supported in the CLIL science classroom through spoken language (but see Nikula, 2017b). The notion of academic language specifically applied to science learning is examined in section 3.4.2.

2.4 Bilingual Learners' Use of Language

The debate on what languages to use for learning when bilingual learners are concerned is a core issue of bilingual education. For a long period of time the educational field has been dominated by the long-held belief of "linguistic purism" (Lin, 2006a, p. 287). The debate over the use of L1 in L2 classrooms has involved both policy-makers and education practitioners (Li and Martin, 2009) and it has so deeply influenced the practice of teaching that moving between languages "has traditionally been frowned upon" (Creese and Blackledge, 2010, p. 105). Even so, Lemke (2002) asks himself:

> Could it be that all our current pedagogical methods in fact make multilingual development more difficult than it need be, simply because we bow to dominant political and ideological pressures to keep "languages" pure and separate? (Lemke, 2002, p. 85)

This study is in line with Lemke's remark and with the many scholars that welcome the overcoming of language purism in classrooms in favour of an environment that promotes communication (Hornberger and Link, 2012; Li and Martin, 2009). This approach implies that languages are not interpreted as static and monolithic systems or "two-solitudes", as referred to by Cummins in bilingual contexts (Cummins, 2008a, p. 2) but rather as dynamic practices functional to sustain communication (García, 2009). According to this framework, rather than understanding students in an L2 classroom as people with two separate monolingual proficiencies (L1 more developed than L2), we see them as drawing from multiple linguistic repertoires in order to communicate and to make sense of their world. We refer to this dynamic process as *translanguaging* (Duran and Palmer, 2013). As a concept, *translanguaging* was originally developed in Welsh bilingual schools (Lewis, Jones and Baker, 2012) and "refers both to pedagogically oriented strategies and to spontaneous language practices" (Cenoz and Gorter, 2017, p. 901). However, a more modern interpretation would consider translanguaging practices more "spontaneous" than strategic and "pedagogically oriented" (Li, 2011, p. 1234; Nikula and Moore, 2019, p. 240). In line with this latter interpretation, García (2009, chapter 3) defines translanguaging as the "engaging in bilingual or multilingual discourse practices". Lin and Lo (2017) extend the meaning of translanguaging to also comprise the notion of academic language. The authors consider as linguistic resources not only L1 and L2, but also everyday language and academic language. They argue that L1 everyday language is an important resource and that "translation practices" also take place between colloquial and academic speaking (Lin and Lo, 2017, p. 29).

Socially, *translanguaging* creates a social space where participants are free from asymmetries of power and can benefit from the permeability of learning across languages (Li, 2011). Finally, *translanguaging* is also a theoretical framework that helps to explore how diverse bilingual students use language in creative and dynamic ways to communicate (García and Wei, 2014). *Translanguaging* is related to code-switching. The latter can be simply described as the use of more than one language in the course of a single speech event (Gumperz, 1982). In this sense, translanguaging comprises code-switching practices but goes beyond them (García, 2009).

An emerging bulk of research is suggesting that minority multilingual learners may achieve better academic outcomes through the exploitation of their multilingual repertories as resources for learning. Examples of this research are, for instance, García and Sylvan (2011), and Hornberger and Link (2012) in the US; Van Viegen Stille, Bethke, Bradley-Brown, Giberson and Hall (2016) in Canada; Rollnick and Rutherford (1996) and Probyn (2015) in Swaziland and South Africa; Creese and Blackledge (2010) in the UK; Karlsson, Larsson and Jakobsson (2018) in Sweden; Beacco (2005) in Europe; Li (2011) in China. Even though most of these studies are concerned with minority-language learners—which are not the typical CLIL students—they are nevertheless relevant for this study as they demonstrate how translanguaging practices and language flexibility are important elements of success in science teaching and learning (e.g. in Lan and de Oliveira, 2019; Poza, 2018).

In CLIL research, there is a dearth of empirical studies on both translanguaging and code-switching practices applied to CLIL in general (San Isidro and Lasagabaster, 2018) and to building content knowledge in particular (but see Moore and Nikula, 2016). In this regard, Moore and Nikula (2016, p. 211) argue that CLIL research so far has mostly adopted a monolingual orientation, despite the fact that CLIL has been advocated "as a catalyst for developing plurilingual attitudes" (Marsh *et al.*, 2001, p. 39), as examined later in this chapter (sections 2.7 and 2.8). For instance, although acknowledging the benefits of code-switching for learning, Domalewska (2017, p. 42) presents it as a repair strategy for low linguistic proficiency, which should "only be used to meet valid pedagogical purposes". Similarly, Zanoni (2018, p. 312) argues that code-switching, "if judicious", can serve as a scaffolding technique, and Lasagabaster (2013, p. 2) advocates for a "principled L1 use, instead of the current randomized practices". Overall, "judicious" and "principled" are a far cry from "spontaneous", as advocated by Li (2011, pp.1223-1224).

By contrast, Nikula and Moore (2019, p. 238) highlight that, in CLIL research, "[o]ne of the issues that has rarely been addressed is integration as a matter of merging language resources involved […], which is surprising given the overall task of CLIL to support the development of future bilinguals". Consequently, very little is known about the potential of translanguaging practices for promoting content (science) learning in CLIL settings. Equally, unknown are the beliefs that CLIL (science) teachers have about creating multilingual spaces for facilitating content (science) learning. After all, most CLIL teachers have been instructed in monolingual settings and it has been demonstrated that a teacher's professional identity and teaching practice are profoundly influenced by what he or she experienced as a learner (Flores and Day, 2006). To date, virtually no research has been conducted on CLIL science teachers' beliefs about language and/or on how these beliefs influence science teaching (cf. Hüttner, Dalton-Puffer and Smit, 2013; Skinnari and Bovellan, 2016).

2.5 A Rationale for Bilingual Education

In this and in the next sections, the reader is guided through a brief journey that describes what bilingual education is and what forms it may take. The aim of these sections is to contextualize and eventually present the CLIL approach.

Bilingual education is a generic concept that refers to the use of more than one language in education. Beyond this basic description, considerable variation can be found depending on the educational context where bilingual education is implemented. According to Baker (1993) the term is sometimes used to refer to the education of students who already speak two languages and other times to the education of students who are learning an additional language. In bilingual education programmes, the additional language is used as a medium of instruction instead of being taught as a subject, which characterises traditional second language teaching (García, 2009). In classrooms, this distinction is not always so clear and García (2009) explains that what really separates these forms of language education are their goals: more broad and cross-culturally oriented in bilingual programmes and more focused on the acquisition of the target language in the case of second language education.

Even though bilingual education is an ancient phenomenon (Genesee, 1987), it is in the last decade that bilingual education initiatives have been growing all over the world (Abello-Contesse, 2013). In general, increasing linguistic diversity is forcing policy-makers and educators to find appropriate ways of educating a growing multilingual school population. Indeed, García (2009, p. 9) highlights that in the 21st century, bilingual children are more the norm than the exception and that "bilingual education, in all its complexities and forms, seems to be the only way to educate as the world moves forward".

Mostly, bilingual education is present in multilingual societies where different languages have a socio-political and/or economic status (Lo Bianco, 2008). Inevitably, bilingual instructional programmes are influenced by socio-political issues and languages are considered either as an instrument for supporting nationalist ideologies or as a mark of authenticity and identity. Alternatively, economic issues may determine the extent to which a language represents an acquirable technical skill and a marketable commodity (Heller, 2002). As a result, political issues and power games are ever present in the debate over the provision of bilingual education (Baker, 2011). This might help to explain, for instance, the contradictory positive picture of bilingualism painted by the Canadian bilingual instruction literature to the negative view of bilingualism in the North American literature (Hakuta, 2011).

There are many different models, programmes and also philosophies of bilingual education. García (2009), Baker (2011), Skutnabb-Kangas and McCarty (2008), and May *et al.* (2004) provide comprehensive examinations of the typologies, approaches and ideologies that characterise bilingual education. A brief overview of these is provided in the next section.

2.6 Approaches to Bilingual Education

As Cazden and Snow (1990) point out, bilingual education refers to a complex and variegated phenomenon which tends to develop into unique forms moulded by a given context. According to the needs it serves, the resources it can access, and the aspirations it holds, bilingual education adopts different forms. And although successful in its own milieu, there is no guarantee that the same form of bilingual education will be as well effective when transplanted in other contexts (Beardsmore, 1993a). As CLIL is a bilingual approach to education (Nikula, 2017a), the main models of bilingual education related to CLIL will be briefly presented here.

Traditionally, the two overarching models, or *philosophies* (May *et al.*, 2004, p. 69), of bilingual education advanced in the academic literature are *subtractive* and *additive* bilingualism. In subtractive bilingualism, the first language (L1) is taken away as the second language (L2) is added. Conversely, in additive bilingualism a second language is added without any loss of the first language (García, 2009). Underpinned by monolingual ideologies, subtractive bilingualism aims at monolingualism in L2. This model can be represented by Figure 2.2.

$$\boxed{L1 + L2 - L1 \rightarrow L2}$$

Figure 2.2 Subtractive Bilingualism (García, 2009, Ch. 3, Fig. 3.1).

Within the subtractive philosophy of bilingualism, the majority language competence grows and coexists with the mother tongue of minority-language speakers only transitionally until the majority language replaces the speakers' first language, which "fades out" and it is usually lost within the third generation (Alba, Logan, Lutz and Stults, 2002). According to Ruíz (1984, p. 17), programmes that adopt subtractive bilingualism are characterized by a "language-as-problem" orientation, because L1 is mainly seen as a problem to overcome as quickly as possible.

By contrast to subtractive models, the result of additive models is the mastering of two languages, as in Figure 2.3.

$$\boxed{L1 + L2 = L1 + L2}$$

Figure 2.3 Additive Bilingualism (García, 2009, Ch. 3, Fig. 3.2).

Originally proposed by Lambert (1973), this general model illustrates how learners acquire and master an *additional* language. Again, according to Ruíz (1984), a philosophy of additive bilingualism is characterized by a "language-as-resource" orientation, because L1 is considered as an asset for developing L2 and achieving academic success.

Within these two broad philosophies, many bilingual education models have been identified and various typologies have been proposed. However, three broad models of bilingual education are consistently referred to for characterizing bilingual education. These are the *transitional* model, the *maintenance* model and the *enrichment* model (e.g. May, 2008). Figure 2.4 outlines these models along a continuum between the transitional model (at the left end) to the enrichment model of bilingual education (at the right end).

Beyond the left end of this continuum, there are several not truly bilingual programmes adopted in the United States to teach English Language Learners (ELLs)—or language-minority students—of immigrant background. These programmes adopt a strong subtractive bilingual orientation and aim to monolingualism (of the majority language) as quickly as possible without using and/or valuing the students' L1 (Skutnabb-Kangas, 1981, 2000). The most brutal programme within these forms of non-bilingual education is *submersion*, also referred to as the "sink or swim" approach, which involves that learners are entirely taught in English without being offered any special language support (Kim, Hutchison and Winsler, 2015). Skutnabb-Kangas (2000) reports that submersion is the most common method for instructing minority-language children. Some other programmes pull out students from their mainstream classes and provide them with English classes for one or two years. Among these, there are the *English as a Second Language (ESL)* programmes, *ESOL (English for Speakers of Other Languages)* programmes and the *Sheltered English-only instruction* (see Short, Echevarria and Richards-Tutor, 2011). Despite the good intentions of these programmes, research suggests that they are not effective at supporting ELLs to catch up with their native-English speaking peers (Crawford, 1999; Thomas and Collier, 1997).

The first broad bilingual model for educating minority-language children is the *transitional* model. The best-known programme within this model is the *transitional bilingual education (TBE),* where two languages are actually used in the classroom for a few years. However, the aim of this programme is to shift students away from using L1 as quickly as possible (de Mejía, 2002) and L1 is only used to support the transition to the majority language (L2). Transitional models of education are also underpinned by a subtractive bilingual orientation. Drawing on evaluation literature on bilingual educational programmes, transitional programmes appear to be the least effective of bilingual programmes (Thomas and Collier, 2002).

The third broad model that is examined is the *maintenance* model. Many bilingual programmes fit into this model. Typically, maintenance bilingual programmes are populated by national minority group members (e.g. Latinos in the USA, Catalan in Spain, Welsh in Britain). The aim of these programmes is to maintain the learners' minority language (L1), to strengthen the linguistic identity of the learners and to guarantee that academic language proficiency in L1 is achieved (May *et al.*, 2004). In maintenance bilingual programmes, students receive a substantial part of instruction in their home language for at least four years (May, 2008). In these programmes, L1 is used as an asset to support L2 development.

In this sense maintenance programmes are underpinned by an additive approach to bilingualism. Research has demonstrated more positive results with this approach to bilingual education than with subtractive approaches (Ramirez, 1991). In general, research in additive bilingual programmes showed that maintenance and development of L1 positively influences oral language, literacy and academic achievements of ELLs (Genesee *et al.*, 2006).

The fourth model is represented by *enrichment* programmes. Within this model, majority-language students are instructed through the medium of a foreign language or of a minority target language. French *immersion* of native English-speakers in Canada is one example of this approach (Genesee, 2013). According to Swain and Johnson (1997, pp. 7-8), there are seven key features that characterize immersion programs:

1. The L2 is a medium of instruction (not the only one)
2. The immersion curriculum parallels the local L1 curriculum
3. Overt support exists for the L1
4. The programme aims for additive bilingualism
5. Exposure to the L2 is largely confined to the classroom
6. Students enter with similar (and limited) levels of L2 proficiency
7. The teachers are bilingual
8. The classroom culture is that of the local L1 community

The Canadian French immersion programmes have been subjected to intensive long-term research evaluation, which produced consistent results that indicate a general effectiveness of the programmes in terms of L2 acquisition and L1 development. Also, there is no evidence of long-term lag in content learning (Cummins, 1998). Elite bilingual programmes (e.g. the International Baccalaureate, IB, programme) in the European Schools are another example of this form of enrichment bilingual education (Beardsmore, 1993b). The two-way immersion (TWI) programmes in the USA also fit into this model. In these programmes, both language-minority students *and* language-majority students are instructed in both languages, meaning in the majority language and in the target minority-language. The TWI are strongly additive forms of education, as they develop bilingualism and biliteracy of both groups of learners, and many research studies identified them as very effective (Cloud, Genesee and Hamayan, 2000; Kim *et al.*, 2015; Lindholm-Leary, 2001; Thomas and Collier, 2002).

The general aim of enrichment forms of bilingual education is to achieve functional bilingualism and biliteracy (Hamers and Blanc, 2000). In particular contexts, these programmes also maintain minority languages (Hornberger, 1991). The European Content and Language Integrated Learning (CLIL) approach (see sections 2.7 to 2.11) fits into this broad model of bilingual education (Nikula, 2017a).

The outlined classification of bilingual education leaves out *heritage* language models. As they are examples of additive bilingualism, May (2008) proposes to situate programmes of heritage language bilingual education (e.g. Hualapai and Navajo in the USA; Maori in New Zealand; Sámi in Finnmark, Norway) between maintenance and enrichment models depending on the L1/L2 status of the students (May and Hill, 2005). Figure 2.4 (modified from May, 2008, p. 5) summarizes what has been outlined so far. The left-hand side represents the subtractive approaches, and the right-hand side the additive approaches.

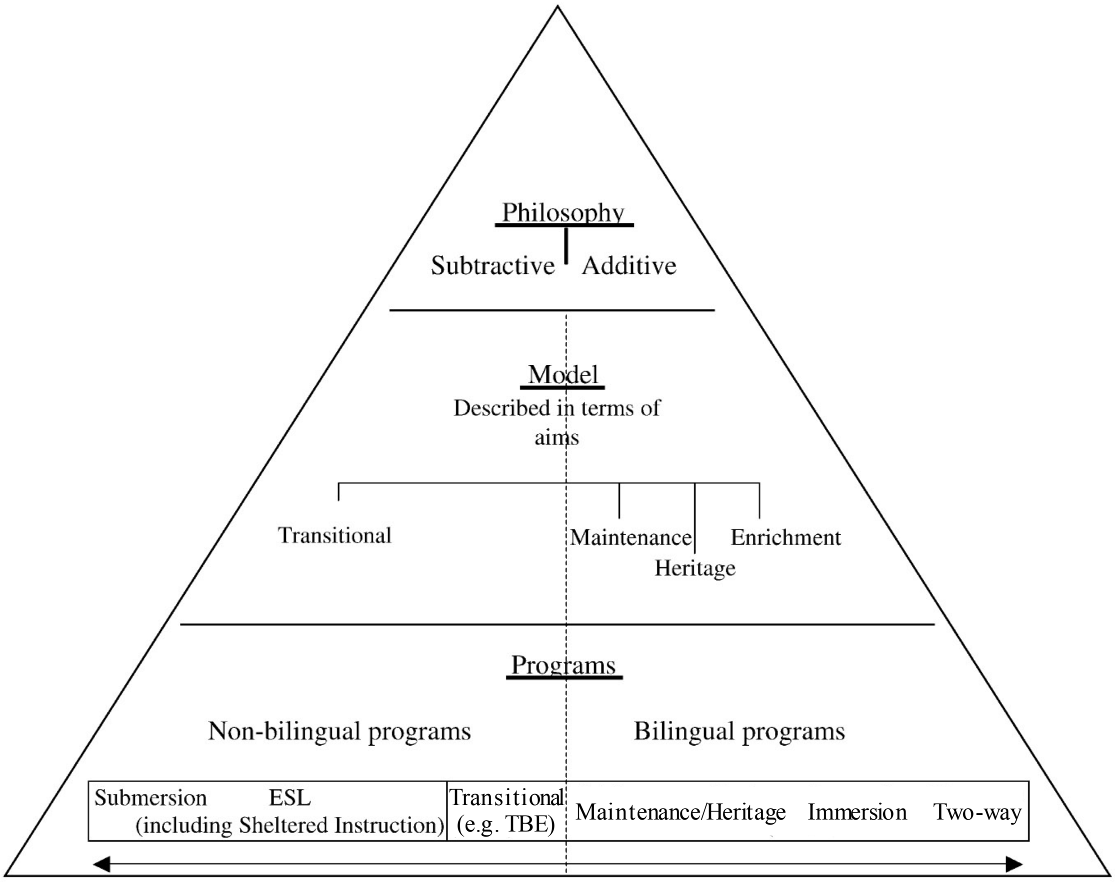

Figure 2.4 Representation of bilingual approaches in education (modified from May, 2008, p. 5).

Overall, a large amount of research supports the benefits of additive bilingual education programmes (Ricento and Wright, 2008). In particular, Ramirez (1991) and Thomas and Collier (2002) provided evidence of the effectiveness of maintenance programmes for minority-language learners. The study by Lambert and Tucker (1972) is only the first of a long series of studies (see Cummins, 1998 for a review) that demonstrate the effectiveness of immersion programmes. In particular, additive bilingualism appears to be associated with overall emergent cognitive and social benefits (Baker and Lewis, 2015; Cummins, 1981a; Genesee, Tucker and Lambert, 1975).

At the heart of the philosophy of additive bilingualism lies the importance of L1 for promoting both L2 development and academic achievements (Cummins, 1979, 1994). Moreover, empirical evidence suggests that the level of development of cognitive/academic language proficiency in L1 is the best predictor of cognitive/academic language development in a second language (Tucker, 2001).

The concept of additive bilingualism is further explored by García (2009, p. 71) who argues that additive bilingualism is "not monolingualism times two" by using an interesting analogy: "more than a bicycle with two balanced wheels, bilingual education must be more like a moon buggy or all-terrain vehicle, with different legs that extend and contract, flex and stretch" making it possible to move forward over highly uneven ground (Figure 2.5).

Figure 2.5 Models of bilingualism, as represented by García (2009).

The uneven ground is the communication between human beings when it occurs among people speaking different languages. The ability to be linguistically flexible, to adapt and opportunistically use all the multilingual resources at hand seems to be advantageous to meet the needs of effective communication and cultural tolerance of the twenty-first century. García (2009, chapter 3) refers to this form of bilingualism as "dynamic". This form of bilingualism, characterizes emergent bilingual students when heteroglossic ideologies have replaced monoglossic ideologies (Flores and Schissel, 2014). Dynamic bilingualism values linguistic tolerance and reflects the modern linguistic need to engage in fluid communicative acts that include the use of multiple languages and of multimodalities (e.g., visuals, texts) to varying degrees of proficiency. This model is very close to the European concept of pluringualism promoted by the Council of Europe (Beacco and Byram, 2002). Ideally, dynamic bilingualism, as well as plurilingualism, extends the idea of mastery of two languages to include also hybrid language practices such as the polyglot dialogue with everyone speaking their language, but understanding everyone else's. Heteroglossic ideologies link bilingualism to the conceptualization of language-as-resource (Ricento, 2005).

2.7 CLIL and Bilingual Education

Content and Language Integrated Learning (CLIL) is referred to as "a dual-focused educational approach in which an additional language is used for the learning and teaching of both content and language" (Coyle, Hood and Marsh, 2010, p. 1). It is generally agreed that the acronym CLIL represents more an approach than a methodology (Coyle, 2002) and that it basically involves a non-linguistic discipline taught in a language of instruction that is not L1 (the first language for the learners) with some (variable) attention to L2.

The concept of a CLIL approach was born in the mid-1990s in Europe to meet the linguistic needs and aspirations of a multilingual-oriented European Union in general, and to enhance mobility and employability of young people in particular (Coyle, 2013). CLIL was originally born for linguistic purposes following the assumption that the teaching of academic content in a foreign language gives the foreign language an authentic purpose (Coyle *et al.*, 2010) and that there are gains in the foreign language over previous practices with no detriment to the learning of academic content (Gajo, 2007). Therefore, through a CLIL approach, content and language are supposedly taught and learnt together and at the same time (Barwell, 2005).

Now, after more than two decades of a steady and rapid growth, CLIL has become the acronym under which bilingual education is promoted within the European Union (Pérez-Cañado, 2012). The term CLIL is generally preferable to the term *bilingual education*, as in certain European countries the latter is politically loaded (García, 2009). Historically, bilingual education has a long tradition in many European countries, such as Luxemburg, which has been offering bilingual education since 1843 (Davis, 1994). Malta, Bulgaria, Estonia and Germany all date bilingual education interventions back before the 1970s (Commission/Eurydice, 2006). More recently, the interest into bilingual education was boosted by the complex and dynamic diversity of European languages, cultures and political agendas. In 1993, Baetens Beardsmore published his study *European Models of Bilingual Education* where he analysed and compared multilingual education in Luxembourg, in Brussels (Belgium) and in the European Schools Network with the Canadian immersion model. In 1995, the European Union through the European Commission decided to set the acquisition of languages throughout Europe as a priority, and CLIL was one of the educational tools devised for accomplishing this goal (Council of the European Union, 1995). In 2006, the

European Commission published its first report on the provision of CLIL in European Union member countries (Commission/Eurydice, 2006), followed, six years later, by a second report (European Commission/EACEA/Eurydice, 2012). The two documents track the spread of CLIL in nearly twenty years since its birth. In 2013, in all European countries (except Denmark, Greece and Iceland), there were primary and secondary schools that provided CLIL instruction, even though the number of schools that offered CLIL was considerably different across countries (European Commission/EACEA/Eurydice, 2012, p. 10). Over the past ten years, there has also been an increase in the production of CLIL resources for practitioners (e.g. The TKT Couse CLIL Module by Bentley, 2010). Boosted by this success, CLIL is now spreading beyond Europe and it is influencing ways in which various non-European countries approach bilingual education. For instance, some Australian bilingual programmes are now being officially referred to as CLIL (Turner, 2013). Similar patterns are observed in mainland China, where the practice of English-medium instruction—often referred to as Chinese–English bilingual education—follows the model of CLIL, rather than that of immersion (Wei and Feng, 2015). A recent interest in CLIL has also been registered in Japan (Ikeda, 2013; Yamano, 2013) and Taiwan (Gosling, 2013).

In terms of its place in education, CLIL shares many elements with other bilingual approaches and especially with immersion (Crandall, 2008; Genesee and Lindholm-Leary, 2013; Nikula, 2017a). This is in line with the fact that the Canadian immersion programmes are often referred to as the predecessor of CLIL (Pérez-Cañado, 2012).

Whereas Coyle *et al.* (2010) claim that the distinctiveness of CLIL lies in the integration of language and content, other authors maintain that a focus on both language and content characterises *any* bilingual programme (García, 2009; Gibbons, 1991). These authors prefer not to insist on the uniqueness of CLIL (Cenoz *et al.*, 2014) and not to distance it too much from immersion programmes (Genesee, 2013) but to rather highlight similarities (Cenoz, 2015; Lasagabaster and Sierra, 2010; Somers and Surmont, 2012). Mehisto, Marsh and Frigols (2008, p. 12) consider immersion programmes as *being* CLIL. Likewise, in the documentation she analysed, Pérez-Vidal (2009) found that the term *bilingual education* was used in the past as we would use CLIL today. In response to this apparent confusion of terms some CLIL key scholars (Lorenzo, Dalton-Puffer, Llinares, Nikula, Lorenzo and Nikula, 2014) prefer to isolate CLIL from immersion programmes by distinguishing the different rationales and social contexts that have shaped the two approaches, while recognizing that bilingual programmes and CLIL have significantly converged over time. In this study, I adopt the perspective that CLIL currently fits within an enrichment model of bilingual education and that it is coming closer to immersion.

2.8 CLIL and Second/Foreign Language Education

Besides interpreting CLIL as a form of bilingual education—especially close to immersion programmes—as explained in the previous section, there is a second narrative. Because CLIL was essentially created for promoting foreign language acquisition, it has also attracted the interest of second/foreign language scholars. As a result, literature about CLIL is deeply rooted in the tradition of foreign language teaching. This explains, for instance, why in the Hornberger's *Encyclopedia of Language and Education* (Hornberger, 2008), CLIL appears not in Volume 5, dedicated to bilingual education and co-edited by Jim Cummins, but in Volume 4, dedicated to second and foreign language education. It also explains the predominant interest in language learning that research into CLIL has exhibited so far and the fact that CLIL research has attracted linguistic researchers from its infancy. This aspect is analysed in sub-section 2.11.

For these reasons, CLIL is by many authors regarded as belonging to second/foreign language education. In second language education research, CLIL's position is often debated. For instance, Dalton-Puffer (2007, p. 3) views CLIL as a natural extension of Communicative Language Teaching (CLT) and Task-Based Learning (TBL) "all rolled into one". Communicative Language Teaching (see Brumfit and Johnson, 1979) is regarded as the currently predominant approach within second and foreign language instruction (Van Deusen-Scholl, 2008). Task-Based instruction is another approach in the family of second/foreign language education, that Pica (2008, p. 71) describes as "characterized by activities that engage language learners in meaningful, goal-oriented communication to solve problems, complete projects, and reach decisions." In this sense, CLIL represents the shift from meaningful communication to meaningful content communication (Coyle, 2007) or to "authentic" communication (Dalton-Puffer, 2007, p. 9).

Most commonly, CLIL has been included in the broad family of Content-Based Instruction (CBI) or Content-Based-Language-Teaching (CBLT) approaches (e.g. by Cenoz *et al.*, 2014; Ruiz de Zarobe and Cenoz, 2015; Stoller, 2008). CBI is defined by Stoller (2008, p. 59) as "an umbrella term referring to instructional approaches that make a dual, though not necessarily equal, commitment to language and content-learning objectives." In CBI, content is understood as non-linguistic subject matter materials "aligned with traditional school subjects, themes of interest to students or vocational and occupational language" (Stoller, 2008, p. 59). CBI encompasses a variety of approaches to integrating content and language instruction that populate a continuum between content driven approaches and language-driven approaches (Met, 1998), as shown in Figure 2.6.

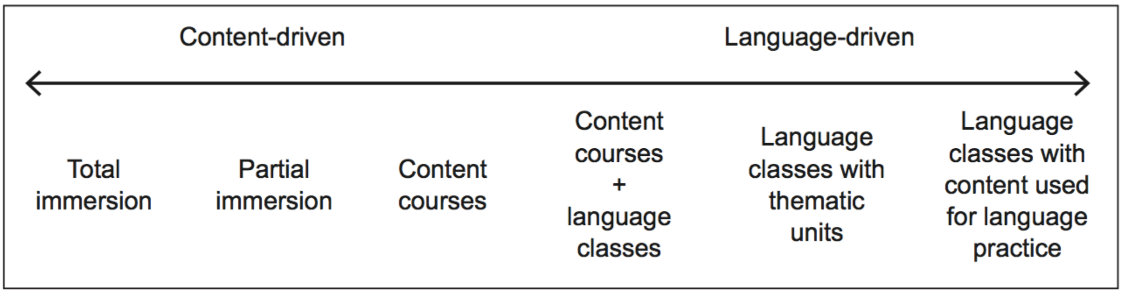

Figure 2.6 Range of CBI settings along a continuum of content and language integration. From Lyster and Ballinger (2011, p. 280) and, originally, from Met (1998, p. 41).

At one end of the continuum, there are found the content-driven language programmes, such as immersion. In these programmes, a non-linguistic subject matter is taught through the medium of a foreign/second language, and the core educational goal for students is the development of content knowledge and language proficiency. Indeed, the Canadian French immersion is oftentimes regarded as the prototypical example of the content-driven approach to CBI (Stoller, 2008). At the other end of the CBI continuum, are language-driven content programmes, characterised by a stronger commitments to language-learning objectives. In these programmes, students learn language as a subject and content serves as a vehicle for contextualising language experiences. Between the two extremes of this continuum there are instructional models that grant equal weighting to both language and content educational goals. According to Stoller (2008) sheltered instruction (already encountered when reviewing subtractive bilingual models) is one of these instructional models (Echevarria, Richards-Tutor, Canges and Francis, 2011).

It can be observed that whereas in bilingual education the approach towards students' L1 is used to distinguish one given form from another, in second language education, it is the dichotomy of content-driven versus language-driven approaches that classifies different forms. Many authors have debated to ascertain where CLIL fits along a continuum between language-driven and content-driven approaches (for example, Lyster and Ballinger, 2011). However, many of them have come to the conclusion that CLIL's position along the content-language continuum varies depending on the given context (Cenoz, 2015). Some scholars maintain that CLIL should strike a sort of 50:50 balance between content and language (e.g. in Cenoz, 2013; Ting, 2011). Other scholars acknowledge the intrinsic variability/flexibility of CLIL forms, referring to it as an umbrella term, similar to CBI. For example, according to Mehisto *et al.* (2008, p. 12), "CLIL is an umbrella term covering a dozen or more educational approaches". More specifically, the variety of forms of instructions called CLIL have been described to range from *strong* CLIL, similar to immersion, to *weak* forms, where the focus is more on the language than on the disciplinary subject (Ball, 2009). In this regard, Paran (2013) proposes to apply to CLIL a bi-dimensional extension of Lyster and Ballinger's characterization of CBI (Lyster and Ballinger, 2011, p. 280). In Paran's conceptualization, different CLIL approaches can be visualized on a diagram with two intercepting continua: an axis of language focus vs. content focus and an axis of language objectives vs. content objectives (Figure 2.7). The quadrants of interest for our purpose are quadrants B and C, which illustrates the two aforementioned variants of CLIL, *weak* and *strong*. In *weak* CLIL the educational objectives are language objectives, but there is a focus on the content, which represents the discussed topic. This corresponds to what Lyster and Ballinger call "language classes with thematic units" (see Figure 2.6). Language literature classes are an example of this. In *strong* CLIL (quadrant C) the objectives are content objectives, but there is still a focus on the language. Here is where most current models of CLIL fit. The classrooms observed in this study also fitted in quadrant C.

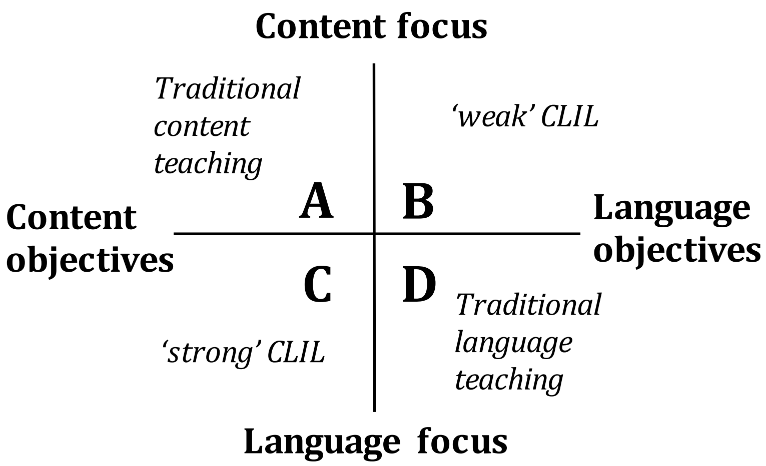

Figure 2.7 The intersection of focus and objectives in content and language teaching (from Paran, 2013, p. 321).

2.9 CLIL in European Classrooms

Today, in Europe, CLIL is typically, but not always, contextualized in classrooms where disciplinary subjects other than languages are taught in English to language-majority students by content teachers who are mostly non-native English speakers. In this study, two teachers were non-native English-speakers and one was a native American English-speaker. The general goal of CLIL is to promote "both content mastery and language acquisition to pre-defined levels" (Mehisto, 2012 p. 15). As with any bilingual education programme, the function it serves vary according to the societies where it exists (Flores and Beardsmore, 2015). In Europe, CLIL education reflects EU policies of promoting multilingualism and CLIL is usually seen as a vehicle for expanding students' skills and consequently increasing their position in society (de Mejía, 2002). Accordingly, it is informed by an *additive bilingual education* model which advocates to develop equal competences in both languages of instruction, without replacing the pupils' first language (Bournot-Trites and Tellowitz, 2002)

Even though any language of the European Union could be the target language of CLIL programmes, English is the most common option (Lanvers, 2018; Lanvers and Hultgren, 2018). CLIL approaches vary considerably in different European countries, according to their cultural, educational and linguistic background (Wolff, 2002b). Grin (2005) identifies 216 types of CLIL programmes based on variables such as: mandatory status, admission criteria, target language, subject, the balance between language and content instruction, intensity, starting age, starting linguistic level, duration, educational goals and pedagogical approaches. Another source of variability is the fact that any teaching approach can be interpreted as a highly personalized enterprise where no two teachers ever teach the same way (Salmon, 1995) and CLIL is no exception. As a result, it is impossible for practitioners to rely on a coherent set of theories and procedures when implementing CLIL. Besides, the potential utility of a fixed reference model has yet to be evidenced. Indeed, research shows that teachers tend to use an existing curriculum in different ways based upon preferences, personal experiences, and beliefs (Brown, 2009; Kazemi and Hubbard, 2008). On the one hand, this could undermine the learning goals of the curriculum, as evidenced by Osborne (2014) in science education. On the other hand, the greatest teacher learning gains have usually been achieved when a teacher actively engages in and reflects upon new practices while adapting a new curriculum to the context (Marco-Bujosa, McNeill, González-Howard and Loper, 2016).

2.9.1 CLIL in German Schools

As this study examines science CLIL classrooms in Germany and Italy a brief overview of this approach in the educational system of these two countries will be provided

CLIL in Germany is commonly known as *Bilingualer Unterricht* (bilingual lesson) which has been offered successfully at mainstream secondary schools since the

1990s. CLIL in Germany is acknowledged as an effective high-quality instructional model (KMK, 2013) and is currently in high demands from parents (Zydatiß, 2017). In 1999, 366 German public schools provided CLIL instruction and by 2013, this number had increased to more than 1,500 (KMK, 2013, p. 4).

The discussion of bilingual lessons in Germany is conducted on the background of a fast-changing Europe under the claim of a "Europe without borders". Thus, foreign language skills are increasingly important. In the Federal Republic of Germany bilingual lessons are viewed as an opportunity to effectively increase foreign language learning within the school context. English, in particular, has infiltrated German education with such a pace and degree that the phenomenon—called *Englishization*—is at the heart of a debate with a growing tension between attitudes of protectionism towards the German language on the one side, and the need for internationalism on the other (Lanvers, 2018). Apart from the open debate on English use in Germany, bilingual education in Germany has a long tradition which dates back to post-war times when it was decided that foreign language learning (in particular French) could promote French-German relations (Küppers and Trautmann, 2013). However, it was in the 1990s that the number of CLIL programmes markedly increased (KMK, 2013). Since then, English as a language medium for learning in CLIL programmes has dominated.

In Germany, CLIL teaching is mainly provided either during individual years, in which a non-linguistic subject is taught in a target language, or in modules, meaning that the teaching of a non-linguistic subject in a target language extends over several weeks (Möller, Fleckenstein, Hohenstein, Preusler, Paulick and Baumert, 2018). The latter approach to CLIL is currently becoming particularly popular as a growing number of parents are asking for it when their children have not been offered the former type of CLIL (Zydatiß, 2017).

Rolka (2004, p. 106) defines bilingual lessons offered by the German public education as "the utilization of *two* learning and working languages in a non-language subject". One learning and working language is German—the native language of the majority of the pupils—and the other one a foreign language: overtly English (Wolff and Marsh, 2007). Traditionally, in most Federal German States ("*Bundesländer"),* the subjects taught at secondary level in bilingual lessons are natural science subjects and social sciences (Möller *et al.*, 2018). The issue of resourcing qualified teachers to teach both a non-linguistic subject *and* a foreign language is where Germany is at an advantage in comparison to some other countries. Indeed, in Germany a teacher needs to be qualified in two school subjects to be employed as a secondary school teacher, which means that the combination of biology or physics or chemistry with a foreign language is principally possible, even though this subject combination is not very common in Germany (Rolka, 2004).

Nevertheless, the situation of German CLIL education is far from ideal. Bilingual lessons are looked at with concern by many German subject teachers that see their subject instrumentalized for the sake of content-based foreign language education (Hasberg, 2004) and the cooperation between foreign language teachers and CLIL content teachers is “far from satisfactory in many cases” (Zydatiss, 2012, p. 63). Even the abovementioned success of CLIL in Germany is currently under scrutiny because it appears to be at least partly due to the selectivity of bilingual programmes (Rumlich, 2016), also referred to as the “distinct elitist tradition” of German CLIL (Apsel, 2012, p. 47). As Bonnet (2012) argues, there is evidence that social selection plays an important role in German CLIL, as both motivation and achievements are prerequisites for entering CLIL programmes. While all students theoretically have access to bilingual programmes, their offer is limited and they are considered more challenging than standard programmes. As a result, good grades, an aptitude for languages and for the non-linguistic discipline that the school provides through a CLIL approach are usually required for enrolling candidate students into CLIL programmes (Meyerhöffer and Dreesmann, 2018). Dallinger, Jonkmann and Hollm (2018) were able to empirically confirm that in history classes this selection produces measurable effects in CLIL groups versus non-CLIL groups. The elitist German approach contradicts the European Commission’s view of CLIL as a means to support students who are unsuccessful in the foreign language classroom.

While some scholars are engaged in debating the elitist nature of CLIL in Germany and how this distorts empirical research into the achievements of CLIL students (e.g. Zydatiss, 2012), others are concerned about the growing dropouts from CLIL streams by students who are unable to meet the increased learning demands (Apsel, 2012). Indeed it appears that there is a growing tension between CLIL as enrichment versus CLIL as a challenge, in particular in light of the societal developments that are marking the German population in terms of the socio-economic context and migration status (Markic and Abels, 2014).

2.9.2 CLIL in Italian Schools

In Italy, CLIL has been institutionalized as an integral and mandatory part of school curricula in all upper secondary Italian school (Langé, 2007), even though its implementation has not spread in a uniform way. Especially in Northern Italy—where CLIL started as a bottom-up initiative before becoming institutionalized—schools, educational institutions and academic institutions have been experimenting and developing CLIL programmes for more than a decade (Infante *et al.*, 2013).

According to the Monitoring Report issued by the Ministry of Education (MIUR, 2014), the most popular foreign language for CLIL in Italy is English. As for the subjects taught in a foreign language, history seems to be the most popular subject, followed by the natural sciences, physics, philosophy, mathematics, art history, and PE. In Italian schools, CLIL has been mainly offered in the form of modules (i.e. units of 10-20 lessons) taught by teams of disciplinary and language teachers working together (Agolli, 2017).

CLIL development in Italy represents a paradox as Italy has been labelled one of the "least multilingual nations in Europe" (Grandinetti, Langellotti and Ting, 2013, p. 355). Italian teenagers are traditionally less at ease when it comes to speaking foreign languages as compared to most of their European peers (Costa and Coleman, 2013). Determined to change Italy's monolingual reputation, the Italian government has made the implementation of CLIL mandatory in the last year of all upper secondary schools since the school year 2014/15 (D.P.R. 87, 2010). The institutionalisation of CLIL in Italy contributed to making this practice both popular and controversial in the country. One of the main issues about CLIL is the recruitment of disciplinary teachers who have a C1 level of competence in the foreign language based on the Common European Framework of Reference for Languages[1] and who have received specific methodological in-service training for teaching through a second language. A second relevant issue stems from the fact that CLIL is mandatory in the last year of upper secondary education, which is the year that culminates in the final state examination. In this exam, students are examined about a given subject in Italian even if they studied it through the medium of a foreign language. To prepare students for the CLIL approach before entering their final year of instruction, the Italian Parliament (2015) approved a School Reform by Law 107/2015 aimed, among other things, to promote the introduction of CLIL instruction at the primary level and upwards. The anticipated implementation of CLIL (mainly in the form of short-term modules) is supposed to strengthen language education and to get students used to learning through a CLIL approach. However, these initiatives have been concentrated in the northern parts of the country (Cinganotto, 2016; Infante *et al.*, 2013). A harder CLIL implementation is reserved for the so-called *licei*

[1] The Common European Framework of Reference for Languages, abbreviated as CEFR, is a guideline published by the Council of Europe (2001) and used as a way of standardising achievements of learners of foreign languages across Europe.

linguistici, which are schools that focus on the teaching of foreign languages. In these schools, the implementation of CLIL is mandatory in the three years preceding the final state exam.

In Trentino—the province where the Italian case study is situated—, historical and geographical factors have traditionally promoted the development of multilingualism. Moreover, a special legal statute grants the Autonomous Province of Trento (PAT) the right to promote legislation on education. Thus, in 2014 the *Project for a Trilingual Trentino* (Provincia Autonoma di Trento, 2014) was launched. The aim was to provide students from a very early age with the opportunity to learn Italian, German and English. CLIL was chosen as the suitable educational approach alongside regular foreign language classes. Since then, CLIL has been widely implemented at varying degrees in many primary and secondary schools. The mandatory implementation of a CLIL approach for teaching a non-disciplinary subject in the last upper secondary year applies also in this province.

2.10 Content Learning and Teaching through a CLIL Approach

As claimed by Lorenzo, Casal and Moore (2009), an important argument in favour of CLIL is the assumption that the focus on content increases the motivation for learning a foreign language (FL). However, it could be argued that CLIL does not cater well for the needs of all the students. In particular, weak students have been observed to perform worse and to eventually drop out from CLIL programmes (e.g. Apsel, 2012). This dropout pattern is not peculiar to CLIL only, but it has also been reported in immersion programmes in Canada (Netten and Germain, 2009). As argued by López and Bruton (2013) students do not necessarily see any point in studying mathematics through English rather than in their first language. On the contrary, it seems more likely that there are high-achieving students who are interested in achieving high grades regardless of the medium of instruction (Muñoz, 2007). Accordingly, in a comparative CLIL and non-CLIL study conducted in Finland, Seikkula-Leino (2007) reports that the most significant differences in maths were actually that the non-CLIL group had a much higher percentage of high-achievers. Overall, it seems that the learning of content in CLIL is still a contentious issue:

> [S]ince the medium of learning is less perfectly known than the LI, this will lead to reduced subject competence either through imperfect understanding or through the fact that teachers preempt this problem and simplify content beforehand. (Dalton-Puffer, 2008, p. 143)

With respect to teaching, CLIL has enormous implications for the role of content teachers who enter CLIL programmes. In general, these teachers believe that working in CLIL programmes benefits their professional role (Vázquez and García, 2017). Becoming a CLIL teacher is both a rewarding and a challenging endeavour. Even though teaching and learning content in L2 is comprehensibly more difficult than in L1, it is also possible to see difficulties as challenges. Challenges may help good practices to gain momentum, to make extra effort worthwhile and to gain the school additional support factors such as language assistants, as was observed in Andalusian CLIL classes (Junta de Andalucía, 2006). Even if they pre-exist to CLIL and even if they are not intrinsic to CLIL, good teaching practices (e.g. active learning, emphasis on meaningful learning, thorough lesson planning, cross-curricular connections and adoption of authentic resources) have been fostered with the incorporation of CLIL (López and Bruton, 2013).

Apart from planning more, spending more time on adapting resources and working closely with foreign language (FL) teachers, content teachers are also expected to maintain a balance between teaching their subject matter and supporting language development. Although teachers claim to be aware of academic-language-related issues (Skinnari and Bovellan, 2016) and of the importance of the content/language integration (Cammarata and Tedick, 2012), the existing research body about teachers' beliefs of CLIL provides empirical evidence that teachers conceptualize the teaching of content and the teaching of language as separated and dichotomous rather than integrated (Karabassova, 2018). In a Finnish study, it was evidenced that most CLIL subject teachers believe that "content plays the primary role in CLIL and foreign language competence, achieved while learning content, is a by-product" (Bovellan, 2014', p. 173). Similarly, in an Austrian study, CLIL teachers felt that foreign language teaching goals were not part of their CLIL classes (Hüttner *et al.*, 2013). A Dutch study on CLIL teaching practices at secondary level revealed that content teaching and language teaching are conceptualized as separated: "We are tribal animals and stepping across the [subject] borders of these sub-tribes we belong to is really difficult for us" (van Kampen, Meirink, Admiraal and Berry, 2017, p. 10). This sense of belonging is even stronger at tertiary level, where lecturers' sense of professional identity is downright that of a subject specialist (Costa, 2013). For instance, Airey (2012, p. 74) found that most Swedish lecturers who teach in English to Swedish students agree with the claim that "I don't teach language, I teach physics". Similarly, an Italian lecturer interviewed by Costa (2013, p. 124) claims that "For us, English is a working tool. Some speak it well, others less so, but no one is put off by this. [...] What's important is getting the message across."

2.11 Research into CLIL

Like the diffusion of CLIL as a practice, research into CLIL has also developed rapidly. As CLIL serves a number of agendas and political purposes, these have inevitably influenced this research. Specifically, CLIL literature tended, at first, to almost exclusively document positive results (García-Guerrero, 2015). In fact, CLIL has often been presented as the *panacea* for many educational issues (Maljers, Marsh and Wolff, 2007) and CLIL-related academic debates have been characterised by a celebratory rhetoric. The list of CLIL researchers that play the role of CLIL advocates is indeed long (e.g. Gajo, 2007; Lorenzo *et al.*, 2009; Lorenzo *et al.*, 2014; Ting, 2010; Wolff and Marsh, 2007). However, in time the overly positive and praising approach ended up backfiring and giving ground to a strong critical strand in the CLIL literature (e.g. Bruton, 2011b; Kirkgoz, 2007; Sylvén, 2013).

Academic debate aside, evidenced-based research into CLIL reveals that it is limited in its scopes (Paran, 2013). For instance, in section 2.4, it was explained how CLIL research has so far neglected translanguaging practices. Overall, CLIL research has traditionally focused on linguistic aspects, adopting a monolingual approach (Breidbach and Viebrock, 2012; Ruiz de Zarobe, 2008). Accordingly, the domain of students' language learning has been covered to a considerable extent (de Graaff, Jan Koopman, Anikina, Westhoff and Koopman, 2007; Lasagabaster and Ruiz De Zarobe, 2010; Nikula, Dalton-Puffer, García and Llinares, 2013). However, after an initial period during which scholars have nearly unanimously praised the benefits of CLIL for language learning (e.g. Lorenzo *et al.*, 2009; Ruiz de Zarobe, 2008; Van de Craen, Mondt, Allain and Gao, 2007; Várkuti, 2010), many authors have become more cautious (e.g. Bonnet and Dalton-Puffer, 2013; Breidbach and Viebrock, 2013). In particular, it is becoming clear that CLIL research has to deal with "a highly contextualized research object" (Dalton-Puffer and Smit, 2013, p. 556), and that great discrepancies exist between CLIL policy and actual teaching practices (Pérez Cañado, 2018). Given that the learning of science through a CLIL approach is the focus of this study, whether the implementation of a CLIL approach may or may not favour the acquisition of the FL is here not a primary concern. An extensive overview of this research area can be found in Dalton-Puffer (2011).

By contrast, content learning in CLIL settings has received far less attention and empirical-based research on it has produced rather inconclusive outcomes

(Bonnet and Dalton-Puffer, 2013). The scarcity of studies on content learning has been ascribed to the variety of disciplinary subjects involved and the lack of standardized tests in non-linguistic subject matters (Dalton-Puffer, 2011). However, this reason only explains the difficulty of conducting large-scale, quantitative studies. Another reason lies in the simple fact that CLIL was born as an approach for promoting language learning (see Commission/Eurydice, 2006; Marsh and Maljers, 2001). In 2011, Dalton-Puffer (p. 184) wrote that "CLIL could be interpreted as a foreign language enrichment measure packed into content teaching". Accordingly, research into CLIL has been mainly attracting language experts (Paran, 2013), who have produced a research body mainly focused on language.

Scarcity aside, empirical-based studies about content learning have so far produced inconclusive outcomes, meaning that the existing studies have produced results that are positive, negative *and* neutral. These results were reviewed by Bonnet and Dalton-Puffer (2013, pp. 273-274) and are here re-examined.

In terms of cognitive gain Van de Craen, Ceuleers, Lochtman, Allain and Mondt (2007), Wolff (2002a, 2007) and Ting (2011) claim that CLIL students develop deeper processing skills, higher flexibility and/or better procedural competences. However, these results are not universally confirmed. For instance, Airey and Linder (2009) found problems in processing scientific disciplinary concepts at tertiary level of education. A decrease in classroom interactions was observed in some Austrian schools (Dalton-Puffer, 2007) and in Swedish upper secondary science classes (Lim Falk, 2008). In Italy, the cognitive demand of observed CLIL lessons have been described as relatively low (Coonan, 2007). Likewise, Gierlinger (2007) found that it was typical in Austrian secondary level classes for the teachers to simplify texts and input to the point that sometimes texts for primary L1 English students were used at secondary level. Kirkgoz (2007) refers to the fact that in Anatolia, Turkey, the authorities stopped mathematics and science being taught in English because of complaints about the university entrance results.

Neutral outcomes have been reported by Jäppinen (2005) in mathematics and science as a result of a large-scale study. Similarly, Bonnet (2004) and Seikkula-Leino (2007) found zero effects on content outcomes. Neutral outcomes have been interpreted as remarkably good results as students are learning content through an imperfect language (e.g. Badertscher and Bieri, 2008). However, a more critical approach towards positive and neutral outcomes is emerging. First, most of the positive results were gathered during a pioneering phase of CLIL implementation, when both students' and teachers' motivations towards the novelty of CLIL were high (Admiraal, Westhoff and De Bot, 2006). Second, Bruton (2011a) warns that CLIL programmes tend to attract students that are academically and socio-culturally advantaged. This selection may result in CLIL students performing better compared to the counterpart of non-CLIL students. This concern has also been voiced by Zydatiß (2007).

Overall, this brief review of the research into CLIL suggests that some caution in judgement with respect to content knowledge would be advisable and that more and deeper research into content learning is necessary. So far, content-focused CLIL empirical research is scarce. The next section examines science learning research in bilingual contexts in general and in CLIL settings in particular. The aim of this part of the literature review is to highlight and clarify the knowledge gap relevant to this study.

2.12 Science Learning in a Second Language

2.12.1 Issues about Science Learning in a Second Language

The increasing emphasis on language and literacy in science education is changing science school curricula and standards internationally, as evidenced in the US *Next Generation Science Standards* (NGSS, 2013), the Irish Junior Cycle Curriculum (NCCA, 2015, p. 7), and the German Rhineland-Palatinate science curriculum (Ministerium für Bildung Wissenschaft und Weiterbildung Rheinland-Pfalz [Ministry for education science and advanced training Rhineland-Palatinate], 2014). It appears clear that science classrooms are becoming, or should become, more *talkative*. Science learning is not *just* about understanding scientific content. It is also about collaboratively communicating, creating, and sharing knowledge, values and identities. Among other things, students need to be able to ask questions, communicate information, actively take part in discussions, engage in arguments and capture both the essential nature and the nuances of scientific reasoning. This is supposed to be accomplished by using a language that is challenging *per se* (see Phillips and Norris, 2009). Inevitably, this increasingly linguistic demand of science curricula (Lee *et al.*, 2013) is raising the academic bar for all students and even more so for bilingual students who are learning science in a language that is not their home language (Hadi-Tabassum and Reardon, 2017). This situation is not dissimilar from that of majority-language learners in developing countries where the official language reflects a colonial history, as in South Africa (Rollnick, 2000). Research conducted in Canada and in the United States among immigrant students of different ages shows that even under the best circumstances it takes most English as Second Language (ESL) children 5 to 7 years to achieve the level of English language competence needed for full participation in school and for performing well on academic tasks (Collier, 1987; Cummins, 1981a; Fillmore, 1986). In these situations, many studies have highlighted that bilingual students' achievements tend to be lower than the achievements of monolingual students (e.g. Lee and Luykx, 2007; Lyon, Bunch and Shaw, 2012). For these students, not only the academic language, but also the everyday language can be daunting (Lee, 2005). In a study conducted in Sweden that compares achievements in upper secondary biology between Swedish students and students from minority-language groups, Nygård Larsson (2011) found that on average Swedish students perform better than students from a non-Swedish background. In particular, limited language proficiency in the language of instruction was observed to systematically restrict students' answers to factual knowledge, and to inhibit access to advanced level of science that require the ability to discuss and explain.

Usually, CLIL learners do not have to cope with social inequalities, cultural barriers and the socio-economic issues that often burden students with non-dominant backgrounds (Osborne and Barton, 1995) or with the negative effects of subtractive bilingualism imposed on minority-language students (García, 2009; Ní Ríordáin, 2008). However, CLIL students still have to deal with the effects of a limited proficiency in the language of instruction on their academic success. In this regard, Nikula and Mård-Miettinen (2014) suggest that CLIL practice and CLIL research may benefit from being informed by research on minority-language learners, which will be reviewed in the next section.

The next two sections explore the existing literature about science learning when the language of instruction is not the first language of the students. The first section deals with minority-language students; the second section outlines research findings about science learning in CLIL settings.

2.12.2 Science Learning and (non-CLIL) ELLs

The body of research dealing with science learning and students with limited language proficiency is relatively new. However, it has grown considerably since the 1990s in response to immigration waves that have been increasing the linguistic diversity in the student population of many countries around the world (Rosenthal, 1996). Back in 1993, Waggoner reported that students from non-English backgrounds represented the fastest growing segment of school population in the USA. Since then, many studies have been devoted to outlining and analysing the science achievements among ELLs. In the USA, there seems to be general agreement about the persistence of gaps when ESL students' academic science achievements are compared to those of native English speakers (Buxton and Lee, 2014; Lacelle-Peterson and Rivera, 1994; Torres and Zeidler, 2002). These data have been confirmed by studies conducted in other countries. For instance, Short (2000) observed similar achievement gaps in science learning among minority-language students in a study conducted in Australia. This result was also confirmed in South Africa (Rollnick, 2000). Tobin and McRobbie (1996) investigated the causes of these gaps in academic achievement. The authors argue that difficulties in English alone are responsible for achievement gaps in Chinese immigrant students in Australia. Despite exhibiting academic commitment, great effort and a single-minded determination to succeed in chemistry, these students were limited by their language difficulties in English. In UK secondary schools, Curtis and Millar (1988) found that science achievements of students of Asian background were limited by their inability to clearly express themselves in the written language. It was observed that only after 8 years of schooling in the UK, the performances of these children became undistinguishable from those of UK children.

The good news is that ELLs are perfectly capable of building appropriate scientific understanding if they are given the opportunity to use alternative semiotic tools combined with their own discursive resources as Duran, Dugan and Weffer (1998) demonstrated in a study with Mexican American students. While becoming proficient with using diagrams and their own language resources, these students became progressively less reliant on the teacher's authority for interpreting biology content and building scientific conceptual understanding.

As a result of an extensive literature review about science learning by ELLs, Lee (2005) concludes that science achievements are strongly related to the level of English proficiency. However, the negative effects of a low language proficiency in English can be—at least partly—counteracted by the following general teaching strategies:

> "(a) teachers need to incorporate cultural and linguistic funds of knowledge that students of diverse backgrounds bring to science, (b) teachers need to examine how students' everyday knowledge and language intersect with scientific practices".
>
> (Lee, 2002, p. 56)

Lee's view is consistent with that of Rosebery, Ogonowski, DiSchino and Warren (2010, p. 323), who call for treating the discourse practices of non-dominant linguistic students "as academically fertile ground". Overall, this research body highlights the importance for researchers and science educators to recognize the cultural and linguistic resources that these students may bring to the science classroom and to incorporate these intellectual resources in science teaching. These resources encompass the students' first language, cultural practices, everyday experiences and metacognitive skills.

Alongside this general approach, other measures have been suggested to facilitate ELLs' access to science. These include the development of linguistically and culturally relevant curriculum materials (e.g. Fradd, Lee, Sutman and Saxton, 2001), language-oriented in-service training for science teachers (e.g. Amaral, Garrison and Klentschy, 2002), and assessment accommodations for ELLs (see Durán, 2008).

The studies described so far have been mainly concerned with the macro socio-cultural aspects of science education. A second group of studies also exists, which are more concerned with the microanalysis of the linguistic features that characterise the academic language of science. These studies typically draw upon the Hallidayan systemic functional linguistic theory (Halliday and Matthiessen, 2004; Halliday and Martin, 1993). Within this second perspective, the focus is on the linguistic aspects of science learning and teaching, and on the linguistic demands of science on ELLs. The general aim of the studies conducted within this perspective is to lower the linguistic barriers and to facilitate the acquisition of language in order to succeed in science (e.g. Echevarria *et al.*, 2011; Fang, 2005; Fang *et al.*, 2006; Mohan and Slater, 2005; Schleppegrell, 2002).

Overall, the socio-cultural contexts of these studies cannot be extended to CLIL contexts. First, CLIL students are generally members of the majority-language group and learning a second language is not likely to pose a threat to their cultural or linguistic identity, nor to the development and maintenance of their first language (Lambert, 1977). Second, by contrast to most minority-language students, CLIL students often belong to the socio-economically advantaged members of the society. However, despite these important contextual differences, some general considerations about content learning that are valid for minority-language students can be also extended to CLIL students. Specifically, teachers can help learners by capitalizing on students' linguistic resources (Lee, 2002), by providing students with opportunities to communicate science through multiple representation formats (Fradd *et al.*, 2001; Lee and Fradd, 1998) and by integrating language and content through the notion of academic language (Fillmore and Snow, 2000). After all, "CLIL is bilingual education and this implies a propensity for multilingual practices" (Nikula and Moore, 2019, p. 239). In the next section, the literature regarding science learning in CLIL settings is explored.

2.12.3 Science Learning and CLIL

In the previous section, research into science learning by minority-language learners (i.e. ELLs) was analysed; in this section, science learning through the medium of a foreign language by majority-language students (i.e. in CLIL and CLIL-like settings) is presented and discussed.

As mentioned in section 2.7, CLIL has been conceived and actively promoted by the European Union through the European Commission to enhance language learning through an instructional model that promotes both language and content. As a result, many students, throughout Europe are now accessing science through a foreign language, mostly English. According to the latest Eurydice reports (European Commission/EACEA/Eurydice, 2012, 2017), English is by far the dominant foreign language taught in Europe and one of the most common languages chosen for CLIL practices alongside German and French. In general, the choice of language of instruction is more the result of language policies than educational reasoning (Spolsky, 2004). Science instruction may represent an exception to this, as science itself has been pointed out as one of the main fields contributing to the spread of English as a *lingua franca* (Ammon, 2011). Although the use of English as a global language for communicating science is not questioned, the feasibility of learning science through a CLIL approach (mostly through English) is highly debated (Bonnet, 2004; Jameau and Le Hénaff, 2018). Some argue that science is inappropriate for bilingual instruction because of the abundance of technical terminology and of the difficulty and abstractness of the topics (Kircher, 2004). Conversely, others argue that science is particularly suitable for bilingual instruction because it has specific characteristics that facilitate understanding in the bilingual setting: the language of the scientific discourse is highly standardised (e.g. easy syntax, no metaphors or irony; Crystal, 1993) it uses many different multimodal representations, such as diagrams, symbols, models and analogies (Tang, Delgado and Moje, 2014) and the enquiry-based approach that characterizes science learning provides many opportunities to engage with concrete objects and to do hands-on experiments (Weller, Bohnsack, Pfaff and Weller, 2009).

With regard to empirical research into science learning in CLIL and CLIL-like settings (i.e. involving majority-language students), this has produced rather inconclusive outcomes marked by striking discrepancies. Outside Europe, Genesee (2004, p. 552) reports that in Canadian immersion programmes (i.e. CLIL-like settings) students instructed in L2 generally achieve the same levels of competence as students taught in L1, provided the assessment is conducted in the L2 and “modifications are made to take into account that full competence in the L2 has not been acquired". Genesee also highlights that this is true both with young (primary level) and with older students (meaning students entering late immersion programmes at 11 years of age), even if the latter are challenged by more demanding academic curricula. The Canadian findings are not supported by the findings from a large-scale study (*N* = 12,784) about science learning in a late English immersion programme in Hong Kong (Marsh, Hau and Kong, 2000). These authors found that Chinese-speaking students scored significantly lower in science, history, and geography than students in Chinese-medium programmes. The authors identified the high linguistic demands of the disciplinary subjects as a primary cause for the negative effects of immersion. It may be argued that it is difficult to compare studies conducted in such different contexts and that a number of factors might explain the contradictory results between the Canadian results and those found in the Chinese study. For instances, the discrepancy may be caused by differences between teachers and/or students, the preparation received during former education, the inherent differences between the respective pairs of languages (English/French and Chinese/English) (Genesee, 2004).

Nevertheless, European studies have produced contradictory findings too. For instance, quantitative studies about science learning by Piesche, Jonkmann, Fiege and Keßler (2016) and Hartmannsgruber (2014) found negative effects of CLIL modules on science learning. By contrast, small scale qualitative studies conducted by Kondring and Ewig (2005) and Bonnet (2004) found no differences in understanding between students instructed in L1 and students instructed in L2. Similarly, Jäppinen, in a large scale (*N* = 669) experimental study (2005) conducted in Finland, found that CLIL learners achieve similar cognitional development levels in science and mathematics to the control group. In contrast to these findings, in a smaller-scale study conducted in Flanders (Dutch-speaking Belgium) to assess the learning gains in mathematics of CLIL (taught in French) and non-CLIL groups, Surmont, Struys, van den Noort and van de Craen (2016) found a significant positive impact of CLIL on mathematical performance. However, it is difficult to say how much the "creaming effect" of selected CLIL students affects these results (Surmont *et al.*, 2016, p. 324) and the results of other studies that compare CLIL with non-CLIL groups (also highlighted by Bredenbröker, 2002; Bruton, 2011b; Rumlich, 2013; Zydatiß, 2007).

Overall, as Piesche *et al.* (2016, p. 110) note, evidence-based research on the effects of CLIL on content learning is "still weak compared with the strong impact of bilingual programmes in schools all over Europe" and findings are too contradictory. The inconsistent nature of results from research into content performance in CLIL studies is likely related to the complex nature of bilingual instruction, which is highly dependent on contextual factor. In this regard, Sylvén (2013, p. 302) identified four important contextual variables that affect CLIL outcomes: "policy framework, teacher education, age of implementation, and extramural exposure to English". According to Sylvén, research studies that pay greater attention to contextual factors are necessary in order to gain a deeper understanding of the meaning of these results. For instance, in a study on mathematics learning and bilingualism from an Irish perspective, Ní Ríordáin (2011) found that bilingual students educated through the medium of Irish perform better than monolingual peers. However, the positive effects of bilingualism found by Ní Ríordáin only appear once students possess a high language proficiency in both English and Irish, which is consistent with both Cummins' Threshold Hypothesis (meaning that only above a given language level the positive benefits of bilingualism con be experienced; Cummins, 1976) and Cummins' Interdependence Hypothesis (meaning the transferability of skills acquired through a language to another language; Cummins, 1979). This Irish study suggests that a closer look at contextual factors and at the interplay between language and the specific disciplinary registers, such as mathematics or science is needed.

However, the existing studies that involve science learning when a CLIL approach is implemented generally display an interest in science education that is not *science-specific*. A selection of CLIL studies produced in Europe is analysed here with respect to their relevance in science education.

The already mentioned study by Jäppinen (2005) explores the cognitional development of learners in an experimental large-scale quantitative study, from 2001 to 2003. The study was conducted in 12 Finnish comprehensive schools, involved students at different school ages (from 7 to 15 years of age), and compared CLIL and non-CLIL science and mathematics classes. Students were taught by their teachers on selected topics and assessed using standardized test to examine how they employed concepts and meanings they had learnt. The findings show that the CLIL learners achieve similar cognitional development levels to the control group. Some difficulties were observed among the youngest learners when they had to deal with abstract concepts. This suggests that teachers should pay particular attention in the selection of the topics to cover in the foreign language when young learners are involved.

Meyerhöffer and Dreesmann (2018) use a quasi-experimental design for comparing learning gains on a newly developed bilingual biology module between a preselected and a non-selected group of students in Germany. In

Germany, CLIL is traditionally being offered only to pre-selected (or gifted) students. The selection for entering CLIL programmes is based on students' previous academic achievements and inclination towards language learning. Currently, this elitist approach to German special school curricula is highly debated (Dallinger *et al.*, 2018). The findings of this study indicate that all participating classes achieved similar gains in content knowledge, which provides evidence that teaching non-selected students bilingually does not lead to deficits in content knowledge acquisition.

Nikula (2015) investigates through conversation analysis how hands-on tasks in CLIL chemistry and physics lessons promote subject-specific language use and learning. The findings of this Finnish small-scale study indicate that the attention to the language of the subject is only implicit throughout the lessons. The author uses these findings as a lever for raising awareness of the importance for CLIL teachers to reflect on their role as language teachers and to explicitly engage in teaching the genres and registers of their discipline.

Evnitskaya and Morton (2011) draw on Wenger's (1998) model of community of practice and explore interactions and the process of negotiation of meaning in two secondary CLIL biology classrooms in Spain. They show how the use of multimodal conversation analysis in classroom research can contribute to better understanding interactions, the use of language and other semiotic tools in CLIL classrooms.

Moore and Dooly (2010) explore multilingual group interactions in a science CLIL teacher training classroom at a university in Catalonia, Spain. The authors use conversation analysis to investigate how prospective teachers use verbal and non-verbal languages to cooperate to build academic discourse and demonstrate how their multilingual repertoires may be an asset for the development of knowledge in a social context.

Even if the above-mentioned studies are concerned with the field of science education, researchers use science mainly as a background to examine other aspects and issues. For instance, Jäppinen's study (2005) aims to validate the CLIL approach against non-CLIL instruction, which is a perfectly legitimate concern that reflects the attention that Finland pays to educational issues. Similarly, Meyerhöffer and Dreesmann's study (2018) aims to understand the effects of students' selection on learning gains. Again, the focus is not on science learning. The mentioned qualitative studies that closely focus on the dialogue of CLIL classrooms, mainly look at science education as an incidental element of their research design, meaning that their aim is not to explore science learning but to understand how academic language is embedded in the classroom talk (Nikula, 2015), or how meaning-making is co-constructed when framed within a sociocultural approach to second language acquisition (Evnitskaya and Morton, 2011; Moore and Dooly, 2010). Also, these studies tend to use linguistic analytical tools, such as conversation analysis. There are a few other studies similar to these that also address science education tangentially (e.g. Escobar Urmeneta and Evnitskaya, 2014; Jameau and Le Hénaff, 2018). Whilst acknowledging the value of these contributions, it is maintained that these studies do not address specifically the science education aspect and do not look at CLIL from the point of view of the science learning and at how this is affected by bilingual instruction.

A few other studies have been found to address more specifically science learning in CLIL settings. However, these are not published in English. The most relevant of these is a qualitative investigation of peer-to-peer interactions in German chemistry classrooms (Bonnet, 2004). In a quasi-experimental research design, groups of bilingual and monolingual students were observed interacting on problem-solving tasks. Bonnet was not able to directly link the use of L2 to conceptual understanding. However, he found that the use of L2 promotes conversation among peers and mediates comprehension.

Summing up, both quantitative and qualitative studies about science education in CLIL settings have tended to look at science education with a focus that is prevalently either on language (Nikula, 2015) or on issues related to the validation of CLIL as a pedagogical approach (Jäppinen, 2005; Meyerhöffer and Dreesmann, 2018; Piesche *et al.*, 2016). In addition, qualitative research into CLIL has tended to adopt a language learning orientation in design, analysis and theoretical framework (Evnitskaya and Morton, 2011; Moore and Dooly, 2010). By bringing these findings together, it becomes clear that very little is known about the effects of CLIL on content knowledge in general (Dalton-Puffer, 2011; Heine, 2010) and on science knowledge in particular. This situation has caused and it is likely to still cause representatives of science teaching to develop an aversion to CLIL approaches (as observed in Haagen-Schützenhöfer *et al.*, 2011).

In the given study, I aim to explore the knowledge gap left by a CLIL research so far focused on linguistic issues and a science education research that has been neglecting CLIL settings. The perspective that is here adopted is that of science education research. In particular, the given study intends to show how CLIL contexts may favour opportunities for learning science by adopting a perspective of language-as-resource (Planas, 2014; Planas and Setati-Phakeng, 2014; Ruíz, 1984).

2.13 Conclusions

This chapter presented the first part of the literature related to this study, addressing bilingual education and the CLIL approach. The chapter was introduced by briefly contextualising bilingual education in its social, cultural and historical milieu. The main features of and approaches to bilingual education were outlined and the most relevant theories to this study explored, with specific attention to the work by Jim Cummins. How language is used in bilingual school settings was then explored. In particular, the concepts of academic language and translanguaging were described. In this regard, a dearth of studies concerning translanguaging practices for building content knowledge in bilingual/CLIL classrooms was revealed. Finally, the CLIL approach was presented and examined with a particular focus on Europe and on its relationship to other types of bilingual educations. For the purposes of this study, the phenomenon of CLIL was also explored in the two countries where data were collected, i.e. Germany and Italy. A systematic review of the existing research into CLIL when content is concerned was conducted and presented. The emerging general picture suggests that CLIL research has been mostly concerned with language learning and that there is a general lack of studies and information about content development in CLIL settings. Moreover, the existing studies on content have produced inconclusive and contradictory results, which appear incompatible with the spread and popularity of this pedagogical approach.

Moreover, the literature about science learning by English language learners was reviewed and socio-cultural differences that separates this research area from CLIL were highlighted. However, possible commonalities between ELLs classrooms and CLIL classrooms were also outlined. Finally, the existing literature that refers to science learning in CLIL settings was systematically reviewed. This literature reveals that CLIL research has been mainly focused on linguistic issues, while science education research has been neglected CLIL settings. In particular, an alarming lack of studies and information about science development in CLIL settings is emerging. To date, virtually no research has been framed within a perspective of science learning and presented in English language. Consequently, very little is known about how science content, science epistemologies and science values are promoted in the everyday discourse of CLIL science classrooms. Also, very little is known about the points of views of teachers and students in relation to science teaching and learning in CLIL settings and how their beliefs and perceptions shape their learning environment. It is the aim of this study to contribute to filling this knowledge gap.

Chapter 3 Exploring Science Education with a Focus on Language

Science is built up of facts as a house is of stones, but a collection of facts is no more a science than a pile of stones is a house.

Henri Poincaré, *La Science et l'Hypothese* (1908)

3.1 Introduction

The first aim of this second chapter of literature review is to provide a conceptual and historical background about science education in general and about the language-related aspects of science education in particular. The second aim is to interrogate the relevant literature in relation to potential research questions while developing an understanding of how this study may contribute to knowledge. The third aim is to develop a theoretical framework specific to this study.

Because this study is *in* science education, this chapter opens by outlining scope and aims of science education in light of how science education research has evolved in the last decades. Literature is examined for its potential to explain how opportunities for learning science are promoted in science classrooms when a CLIL approach is adopted (i.e. the main focus of this study). Accordingly, aspects and theories of science education research that are specifically concerned with language-related issues are examined. Particular attention is payed to how spoken language is used in the classroom to build science (namely, classroom discourse). Finally, a suitable theoretical framework that guides the methodologies for collecting, analysing and interpreting data is developed.

3.2 Aims of Science Education

There are several ways by which science has been defined. Among others, the New Zealand Ministry of Education acknowledges that:

> Science is a way of investigating, understanding, and explaining our natural, physical world and the wider universe. It involves generating and testing ideas, gathering evidence by making observations, carrying out investigations and modelling, and communicating and debating with others in order to develop scientific knowledge, understanding, and explanations. (New Zealand Ministry of Education, 2007, p. 98)

Translating these different elements into school curricula poses challenges for educators and policy makers involved in curricular reforms internationally. As a result, school science is a very dynamic concept that reflects the complex relationship between shifting pedagogic perspectives and evolving views of learning (Dillon and Manning, 2010).

In terms of curricula, science education was traditionally focused on what students need *to know* about science (Schwab and Brandwein, 1962). In the 1990s, the focus of science education shifted from what students know, to how they know and what they need to do to learn science (Duschl, 1990). A third, and more recent paradigm in science learning reflects the shifting of beliefs about school scientific literacy from a knowledge-oriented (OECD, 2003) to a socioculturally-oriented concept where the learning is situated in social practices (Roth, 2007; Sadler, 2009).

As far as the pedagogic perspectives are concerned, they have moved from transmission modes, to more constructivist (Monk and Dillon, 1995) and sociocultural approaches (O' Loughlin, 1992). Also, the range of knowledge, skills and competences to be taught at school has been subject to debate and scrutiny. To effectively understand that school science is not a simple "miscellany of facts" (Osborne, 2013, p. 266), students need to be offered the opportunity to comprehend how scientific knowledge is built, so that they can see that science is a rational endeavour where each discovery is based on the evaluation of evidence (Duschl, 2008). Osborne, Collins, Ratcliffe, Millar and Duschl (2003, pp. 704-705) explored the opinions of leading scientists, science teachers, science communicators, historians, philosophers, sociologists and science educators about what should be part of a school curriculum. The participants to the study agreed that at least nine features should be taught in school science. These are: (1) scientific methods and critical testing; (2) the relationship between the methods of science and certainty; (3) the diversity of scientific thinking; (4) the role of hypothesis and prediction; (5) the historical development of scientific knowledge; (6) the role of creativity in science; (7) the relationship between science and questioning; (8) the analysis and interpretation of data; (9) the role of cooperation and collaboration in the development of scientific knowledge.

It is apparent from this collection that science education is more about a way of understanding how science works (i.e. the nature of science) than a collection of knowledge. The rationale behind this discussion is that being scientifically literate is an important requirement for an informed citizenry. Citizens who understand how scientific knowledge is built take better care of their body and of the environment, are careful consumers and are more knowledgeable voters as they are better judges of claims about scientific issues such as ecology, genetically modified food, alternative medicine (Duschl, Schweingruber and Shouse, 2007).

3.3 Nature of Science (NOS)

As evidenced by the previous section, developing an understanding of how science works is at least as important as learning the content of science knowledge. Since the 1990s, there has been a call from many scholars engaged in science education (e.g. from Lederman, 1992; McComas, Almazroa and Clough, 1998) to not only teach what Duschl (1990, pp. 68-69) calls the “final form” of science (i.e. science facts) but to also devise instructional interventions that develop epistemological views of science as a “process of building and revising model and theories about the world” (Sandoval and Reiser, 2004, p. 346). This perspective of science is a construct that has been labelled as the *nature of science* (NOS) and dates back to the works of Aikenhead (1979), Carey and Stauss (1968) and Lederman (1986) based on investigations about teachers’ and students’ beliefs about science.

A comprehensive bibliography primarily focused on empirical research on NOS as an educational goal is provided by Bell, Abd-El-Khalick, Lederman, McComas and Matthews (2001). Lederman, Abd-El-Khalick and Schwartz (2015, p. 704) define NOS by referring it to the “characteristics of scientific knowledge inherently derived from the manner in which it is produced”. Lederman (2007) provides a detailed description of the characteristics that describes what NOS is concerned with, e.g. the distinction between observation and inference, the social and cultural sphere of scientific knowledge, the inherent tentativeness of science. He also explains that NOS does not equate to epistemic practices (i.e. the processes of inquiry), as NOS is essentially a cognitive construct that highlights the epistemological underpinnings of scientific knowledge. While Lederman (2007) suggests to leave the processes of inquiry out of what NOS is concerned with, Duschl and Osborne (2002) disagree arguing that they constitute an important component of NOS. A similar stance is taken by Irzik and Nola (2014), who propose a comprehensive framework for what is meant by NOS, further expanded by Dagher and Boujaoude (2015) and Dagher and Erduran (2016). In particular, Dagher and Boujaoude (2015) argue that science is essentially a cultural enterprise that cannot be isolated from the culture in which it is produced and practiced by bringing forward examples of how political agendas and religious thoughts infiltrate cultural perspectives and influence values and attitudes towards science.

The importance of explicitly teaching NOS as part of the science curriculum is widely recognized (see Akerson, Buck, Donnelly, Nargund-Joshi and Weiland, 2011; Clough and Olson, 2008; McComas *et al.*, 1998) as is evidenced by an extensive NOS literature appearing in science education journals (Clough and Olson, 2008) and by many science education reform documents, e.g. the Irish Junior Cycle Curriculum (Erduran and Dagher, 2014; NCCA, 2015, pp. 10-11), the New Zealand Science Curriculum (see Hipkins, 2012), the US Next Generation Science Standards (Appendix H in NGSS, 2013).

However, despite the general consensus regarding the importance of explicitly teaching the NOS, "much remains to be done in moving the vision to a reality" (Clough and Olson, 2008, p. 143). So far, research into Science Education on NOS has been mainly focused on students' beliefs about science (Driver, Leach and Millar, 1996), teachers' understanding of NOS, particularly prospective teachers (Abd-El-Khalick, Bell and Lederman, 1998), and on teacher's implementation of NOS as teaching goal (Herman, Clough and Olson, 2013a, b).

Even though there have been numerous studies on students' and teachers' understandings about the nature of science (Bell *et al.*, 2001), few investigations about NOS have been focused on observable classroom practices (e.g. Brickhouse, 1990) and even less on classroom discourse. In one of these works, Ryder and Leach (2008) investigate how teachers transform their personal understanding of the epistemology of science into pedagogically suitable talk. The characteristics of classroom discourse that these two researchers found out as conducive to promoting the learning of the epistemologies of science are: (1) making *explicit* the epistemic learning aims to focus student learning; (2) linking epistemology to content by exemplifying or contextualizing epistemic aspects within content areas; (3) demonstrating how epistemic ideas underpin the developing of science knowledge by linking science content from other lessons.

To date, very little is known about how the teaching of the nature and practices of science is supported by classroom discourse in bilingual settings. Peripherally related to this is the work by Lee and Fradd (1996a). The authors found that some science values and science epistemologies are grounded in instructional discourse practices (such as logical argumentation, scepticism, questioning and criticism) that may be incongruent to some languages and cultures. Similarly, Brown (2004) recognizes science teaching and learning in multicultural settings as culturally sensitive. However, apart from issues of cultural congruence, very little is known about how science values and epistemologies can be promoted and taught through classroom discourse in bilingual (CLIL) classrooms. So far, nothing is known about how CLIL teachers promote an evidence-based culture through classroom discourse, or about what kind of ideas of science knowledge CLIL students develop. This study may contribute to shedding some light on this aspect of science teaching and learning in bilingual settings.

3.4 Language and Science Learning

This section is concerned with two language-related aspects of science education. The first aspect refers to the fact that a learner's language structure and knowledge structure are closely entwined (Olson, 2017). The second aspect is concerned with the fact that the language through which science is taught and learnt is markedly different from the everyday language that students use outside school (Fang *et al.*, 2006). These two aspects affect any science learner; however, students not yet fluent in the language of instruction are more sensitive to these aspects since they have to learn content by using a language that they are still developing. The first aspect is developed in the next section 3.4.1. The second aspect, specifically concerned with academic language in science education, is addressed in section 3.4.2.

3.4.1 The Role of Language for Science Learning

Richardson Bruna, Vann and Perales Escudero (2007) note that, although science is often considered a practical subject, science learning relies heavily on the use of language. Similarly, Lemke (1990, p. 153) argues that "the mastery of science is mainly a matter of learning how to talk science". Within science classrooms, language is an effective communication tool used both for transmitting (scientific) knowledge (Mercer, Dawes, Wegerif and Sams, 2004; Rivard, 2004; Strauss and Shilony, 2009), for reflecting and developing (scientific) thoughts (Vygotsky, 1986) and for negotiating meaning (Driver, Asoko, Leach, Mortimer and Scott, 1994; Sutton, 1996).

The key role of language in science learning is rooted in the posthumous dissemination of the work by Lev Vygotsky (1986) and dates back to the 1960s, when Vygotsky's *Thought and Language* was first introduced in English speaking countries. Along this line, Halliday (1978) argues that the learner thinks with the language, which is part of the thinking process itself. Not only does language support peers and student-teacher interactions, but it also provides a tool for shaping/eliciting children's ideas and existing knowledge and for helping them interpret and construct meaning. Sfard (2008, p. 81) explores the interesting thesis that thinking is indeed "an individualized version of interpersonal communication". The author proposes the adjective "commognitive" as the result of the combination of cognitive and communicational. The idea that the language structure impacts on cognitive systems and consequently on thought processes is known as the linguistic-relativity hypothesis (Sapir, 1949; Whorf, 1956). There is evidence that even the development of mathematical thought, which uses a “universal language” is nevertheless sensitive to cultural differences, language included (Kim, Ferrini-Mundy and Sfard, 2012; Poisard, Ní Ríordáin and Le Pipec, 2015).

The scope of research into the role of language in science education ranges from vocabulary (Cassels and Johnstone, 1985; Marshall, Gilmour and Lewis, 1991), connectives (Gardner, 1975, 1977), scientific register (Halliday and Martin, 1993) teacher’s explanations (Ogborn, Kress, Martins and MacGillicuddy, 1996), science reading (Davies and Greene, 1984; Halliday, 1998) and classroom discourse, which alone has a well-established and articulated research tradition, which is examined in sections 3.5 and 3.6.

Thanks to the fact that the language of science has specialised sets of words and offers standardized ways of speaking, it has also attracted the attention of scholars from outside the science education community with interests in linguistics. A notable example are Halliday and Martin (1993), who contributed to characterizing the scientific language by applying the principles of systemic functional linguistics, or SFL (Halliday, 1978).

Within a sociocultural perspective on learning, language moved from being viewed as a means for conceptual acquisition to becoming an instrument for the social construction of knowledge through participation (Carlsen, 2010; Kelly and Sezen, 2009). Accordingly, language plays a key role in the co-construction of knowledge, culture and identity (Brown, Reveles and Kelly, 2005). This view of classroom language reflects what happens within communities of practice where scientists interact with one another by using specific oral and written discourses (Green and Dixon, 2008). Thus, language, in the form of discourse, shapes the ways of thinking, knowing, doing and being within the science classroom (Gee and Green, 1998). This perspective of language and discourse theoretically frames this study.

3.4.2 Academic Language of Science and Everyday Language of Students

The general notion of academic language was examined in the previous chapter, in section 2.3. Here, the same concept is examined when specifically applied to science education. Science education is one of the fields where academic language research has been more prolific as “[n]o domain represents academic sorts of language better than science” (Gee, 2004, p. 19). The academic language of science has indeed been acknowledged as part of the “hidden curriculum”

(Cazden, 1993, p. 12). On the one hand, the academic language of science structures scientific knowledge and connects an international science community (as noted in previous section 3.4.1). On the other hand, the complexity of science language (examined in next section 3.4.3) generates unique learning problems (Brown, Donovan and Wild, 2019) in particular when bilingual students are involved (Brown and Ryoo, 2008). Accordingly, many studies in science education concerned with academic language are settled in bilingual learning environments (e.g. Brown, 2004; Lee and Fradd, 1996b; Moje, Collazo, Carrillo and Marx, 2001), where academic language has a strategic value, as it highlights the specific language-related challenges that students learning science through a second language may encounter (Richardson Bruna *et al.*, 2007).

For this reason, some researchers in multilingual science education advocate the use of a "hybrid discourse", which mixes everyday language and scientific ways of speaking for enhancing science content understanding (Brown and Spang, 2008, p. 731). This approach is conceptually not very dissimilar from translanguaging (examined in section 2.4), meaning here that a child's academic success is facilitated by a repertoire of linguistic resources that also capitalizes on everyday language (cf. Lin and Lo, 2017). According to Brown and Ryoo (2008), students understand new science concepts better and retain science content at greater rates if they learn science through a simpler language prior to being taught scientific language. Also, moving back and forth between science language and everyday language in a circular way has been found to support science comprehension (Lan and de Oliveira, 2019). Furthermore, a teacher's use of everyday language in the science classroom dispels the notion that scientific understanding resides in the terms and is coherent with Arons' idea that "a scientific concept involves an idea first and a name afterward" (Arons, 1983, p. 92). Moreover, science academic language seems to intimidate students by sending "a subtle message that an individual 'belongs' or 'does not belong' to a community" (Brown *et al.*, 2019, p. 4). In particular, in their randomized experimental study, Brown *et al.* (2019) demonstrated that the socio-affective domain of secondary level students instructed on the water cycle was negatively affected by complex scientific language and resulted in a reduced working memory capacity. The hypothesis that specific ways of using language can foster (or hinder) the development of more than conceptual understanding was also examined by Moje (1995), who found that a science teacher's focus on precision in using the academic language of science resulted in students heavily relying on the teacher's authority instead of trying and experimenting themselves with the language of science. In this regard, Lemke (1987) also highlights the need for linking science terms to everyday ways of speaking.

So far, little is known about how science teachers in CLIL classrooms promote the development of academic language and about the role that everyday language plays in the building of science knowledge (see Nikula, 2017b). Furthermore, no studies exist, to date, in CLIL research (or in science education that investigates CLIL settings) that look at academic language *and* everyday language as meaning-making resources.

3.4.3 Characteristics of Science Language

There is a widespread agreement that science has a language of its own (Kearsey and Turner, 1999). This was very apparent to me when in November 2018 the International Bureau of Weights and Measures announced a revision of the International System of Units (SI) at its 26th General Conference (CGPM). It was announced that the mass of the international prototype of the kilogram was abrogated and a new definition of the kilo was introduced based on the precise measurement of the Planck's constant, that relates weight to electrical current (CGPM, 2018). The news made the headlines for several days. Most journalists failed to provide a scientific explanation and only reported that the original little block of platinum-iridium had been replaced by a *maths formula*. Unfortunately, scientists who made an effort to explain this change only reached a minority of the population. This case exemplifies how the language of science is definitely different to everyday language, and how it can become a cultural barrier affecting science understanding. At school, students need to understand and acquire this language in order to access science, to communicate in science and to think scientifically. The language of science is particularly challenging because of its idiosyncratic vocabulary, registers and taxonomies (Wellington, 1983). Osborne (1996, p. 274) argues that "learning about physics is more akin to the learning of a foreign language than it is to the learning of historical facts". Similarly, Baker (1991) demonstrated that learning science in a first-year biology course required more new vocabulary than a first-year Spanish course. These aspects of science language make science learning in bilingual settings even more challenging, as science language adds a further linguistic code when the language used as a medium of instruction is not perfectly mastered.

The language of school science, written or oral, is characterized by abstraction, precision, objectivity, conciseness, high density of information-bearing words and expression (Snow, 2010), and there is abundant use of analogies and metaphors (Reeves, 2005). Not only does it contain a great number of specialist terms and technical taxonomies, it also uses these words frequently as they guarantee a precise and efficient way to communicate (Martin, 1993). As a result, the language of science has a high lexical density, measured as the number of lexical items or content words per clause (Schleppegrell, 2001). To make things even more complicated, the specialist terminology of science does not only encompass words that belong to a specific domain of science (e.g. macromolecule) but also incorporates words from the everyday life that, when used in a scientific context, acquire a very specific meaning removed from their everyday usage (e.g. work, bond, host). However, even though disciplinary terms are a fundamental part of scientific language, they are not the whole story. Halliday and Martin (1993) argue that the unicity of scientific language lies not just in the words, but in the lexicogrammar as a whole. According to the authors, the nominalization of adjectives, verbs and even sentences ("noun phrases") are the most distinctive features of scientific language, which is at least partially responsible for alienating people—such as children at school—from the scientific discourse. Halliday and Martin's analysis was produced within the Systemic Functional Linguistics perspective (SFL), which considers language as a resource for meaning-making, i.e. a semiotic resource. Lemke (1990) reworked and adapted the SFL perspective to the science classroom talk and analysed how verbal language is a resource for scientific meaning-making. At the core of his analysis of the science verbal discourse, Lemke places chunks of meaningful scientific content, that he calls *thematic patterns*. A learner needs to be able to build thematic patterns in order to understand and learn science. Thematic patterns are combinations of *thematic terms* that work together in a network of semantic relationships to describe the science content. Science learning occurs as a process of understanding linguistic patterns and acquiring the functional uses of science language in the classroom (Lemke, 1990; Wenger, 1998).

Finally, the language of science is multimodal, meaning that science concepts are described and communicated through different modes of representations, such as symbols, gestures, graphs, diagrams, maps, models (see Jewitt, Kress, Ogborn and Tsatsarelis, 2001; Kress, Jewitt, Ogborn and Charalampos, 2001). There is evidence from multimodal analysis of classroom communicative events that the meaning of the overall message is distributed across different semiotic modalities, and not necessarily evenly (Jewitt *et al.*, 2001; Kress, Ogborn and Martins, 1998). Kress *et al.* (1998, p. 72) identified four major communicational modes: "talk; images; gesture; the physical/material apparatus", with talk dominant and nearly omnipresent but with different functions: sometimes as the major mode and sometimes to background the other modes. Prain and Waldrip

(2006) demonstrate that the ability to grasp the meaning and link between different modalities appears to be affected by the learner's familiarity with a particular representation and cognitive style. Ainsworth (2006) suggests that the more the formats of the representations differ, the more difficult it will be for learners to integrate information across them. These aspects are particularly relevant in a bilingual science classroom, where there is a powerful call for implementing multiple representations as a way to lessen the linguistic barriers (Lin, 2012; Lo and Lin, 2015).

3.5 Science Classroom Discourse

Discourse is commonly defined as the use of language within social contexts (Gee, 1989). In science education, the concept is more complex in definition and closer to what Gee (1989, pp. 6-7) labels as Discourse with the capital "D" and defines as the combination of "words, acts, values, beliefs, attitudes, and social identities". Discourse is more than classroom talk, as verbal communications are only the manifestations of the underpinning perspectives of the individuals. Discourse also encompasses the approach these individuals choose for communicating and the pattern of interactions.

The importance of discourse in the science classroom is highlighted by Lemke (1990, p. 24) with these words:

> Just as with learning a foreign language, fluency in science requires practice at speaking, not just listening. It is when we have to put words together and make sense, when we have to formulate questions, argue, reason and generalize, that we learn the thematics of science.

Lee and Fradd (1998, p. 15) note how discourse has become such a central and integral component for learning academic disciplines that learning science encompasses not only the issues of "knowing science" and "doing science" but also of "talking science." Accordingly, recent science-education reforms have foregrounded students' ability to "talk science" (e.g. Lee *et al.*, 2013). Furthermore, a particularly prolific line of research on science classroom discourse has been thriving for last three decades (e.g. Chin, 2006; Kawalkar and Vijapurkar, 2013; Kumpulainen and Rajala, 2017; Lemke, 1990).

In this and in next section 3.6, literature that refers to science classroom discourse is analysed with a focus on discourse formats (e.g. triadic dialogue), and on discourse functions (i.e. knowledge building, scientific sensemaking and metadiscourse).

3.5.1 The Triadic Dialogue in the Science Classroom

A great amount of empirical studies have demonstrated how teachers often dominate and orchestrate classroom talk. Many studies have revolved around the role of the teacher as facilitator of effective classroom discourse, especially by focusing on patterns of interactions (e.g. Sinclair and Coulthard, 1975; Viiri and Saari, 2006), on communicative approaches (e.g. Mortimer and Scott, 2003; van der Veen and van Oers, 2017), and on teacher questioning (for instance Chin, 2007; Kawalkar and Vijapurkar, 2013). Most of the studies that focus on the role of the teacher as facilitator of classroom discourse draw from the seminal work by Sinclair and Coulthard (1975), which laid down the analytical framework for describing classroom interactions. Sinclair and Coulthard's interest was mainly in the linguistic patterns of the discourse, rather than in pedagogical and content-related aspects. In particular, Sinclair and Coulthard focused on the recurrent sequence of moves that represent the most frequent exchange type found in classrooms, i.e. the exchange composed of Initiation-Response-Feedback (IRF), or Initiation-Response-Evaluation (IRE) (Mehan, 1976). Lemke (1990, p. 8) refers to the dialogue based on this kind of exchange as the "triadic dialogue" and considers it to be pervasive in the science classroom. Similarly, Wells (1993, p. 1) estimates that this format of exchange accounts for up to 70% of all talk between teachers and students and he argues that "[i]f there is one finding on which learners of classroom discourse agreed, it must be the ubiquity of the three-part exchange structure". After more than four decades since Sinclair and Coulthard's study appeared, today's science education scholars generally agree that the triadic dialogue pattern is not only ubiquitous but also dominant (e.g. Alexander, 2008; Chin and Osborne, 2008; Geelan, 2012).

Nonetheless, its use is debated. In this regard, one of the most frequent critiques against the IRF/IRE structure focuses on its inherent lack of authenticity, meaning that the teacher is merely following a "recitation" script (Cazden, 2001, p. 31) with pre-established answer (e.g. in Alexander, 2005; Lemke, 1990; Tharp and Gallimore, 1991) while transmitting pre-packaged knowledge (e.g. Lyle, 2008). Ballenger (1997, p. 11) describes this kind of format "as a powerful impediment to authentic conversations in which multiple perspectives, students' and teacher's, come into contact". The second important critique regards the asymmetrical nature of the relationship between teacher and students that this dialogue structure emphasises (Lyle, 2008). A third critique is concerned with the assumption that IRF/IRE sequences only trigger recalling, and that they neither support reasoning nor the building of collaborative knowledge (e.g., in Wilson, 1999). In general, the studies that are critical towards the IRF/IRE structures are not concerned with the teaching purpose or the content of the lesson. To other authors IRF/IRE questions serve a purpose to stimulate and challenge students (Baynham, 2006). Furthermore, Mercer (1992, pp. 218-219) justifies the triadic talk as effective for monitoring and guiding students' learning, and for "marking knowledge and experience which is considered educationally significant or valuable". Similarly, Nassaji and Wells (2000) found evidence that the IRF sequence allows the teacher to check students' knowledge or understanding and to make repairs if necessary. In particular, the last slot of the sequence, i.e. the feedback move, can serve important pedagogical purposes as it can be used to probe, to challenge, to ask students to expand/extend. In these cases, the series of IRF extend to IRFRF chains (Mortimer and Scott, 2003) and eventually allow students to further build on their own reasoning.

Not only has the IRF/IRE discourse structure sparked off an intense debate in science education, it has also nurtured research methodologies for understanding and describing instructional communication, such as classroom discourse analysis (for example in Van Booven, 2015), classroom interactional analysis (e.g. in Dohrn and Dohn, 2018), or conversation analysis (for instance in Morton, 2012). These studies adopted a variety of different foci, such as social interactions (Gillies, 2016), disciplinary literacy (Rappa and Tang, 2018), or content development (e.g. van der Veen and van Oers, 2017). Numerous studies have also focused on the quality of reasoning triggered by the classroom talk. For instance, Hogan, Nastasi and Pressley (2000) found that teacher-lead interaction sequences—i.e. teacher-guided discussions—are an efficient way for generating and maintaining high quality chemistry explanations and high degree of scientific reasoning, whereas peer dialogue is more productive when the generation and exploration of new ideas is the pedagogical goal. Nathan and Knuth (2003) showed that teacher-led dialogue offered higher level of mathematical precision than student-led discussion. These empirical studies, which value context and pedagogical goals, look at the triadic dialogue under a different light and their findings support Wells' thesis (1993) that the triadic dialogue is itself neither good or bad as it ultimately depends on the purpose it serves. Different teachers may use it in very different ways and even the same teacher may use it in different contexts for achieving a variety of purposes in ways that are not yet entirely understood (Viiri and Saari, 2006). As Stables (2009, p. 8) notes, "[t]he various and skilful ways in which some teachers use even the limited IRE or IRF pattern is arguably still not fully recognized." Furthermore, Chin (2006) identifies a need for better understanding of the F-component of the IRF sequence and suggests that "future research could look into the differential effect of different types of feedback, the conditions under which different types of feedback are most effective in mobilizing students' ideas" (Chin, 2006, p. 1341).

Overall, what emerges from these studies is that teachers play an important role in leading the classroom talk towards specific educational goals and in ensuring that students are engaged in appropriate cognitive activities. Even when the whole-class exchanges are in the IRF form, they help students "to articulate and elaborate on what they were thinking" (Chin, 2007, p. 837). Thus, the IRF sequence allows teacher-led whole class conversations, "and is a sort of large-scale scaffolding" (Dawes, 2004, p. 682).

Both the first and the third move of the IRF sequence—i.e. questions and feedback—have attracted the attention of researchers for their potential to encourage, stimulate and support cognitive engagement and high level of reasoning (e.g. Louca, Zacharia and Tzialli, 2012). In addition, the triadic dialogue has been observed to be effective with science students who are still learning the language of instruction, as long as literacy elements are incorporated in an inquiry-oriented dialogic instruction (Haneda and Wells, 2010). Dalton-Puffer (2007, p. 75) argues that in CLIL classrooms, the IRF pattern "forms the foundation of language-based learning".

3.5.2 Monologues in the Science Classroom

Teachers' monologues, i.e. lecturing, is generally considered an undesirable form of teaching, "almost a form of taboo" (Dalton-Puffer, 2007, p. 91) which has been labelled as a negative practice since the 1970s (Borg, 1972). As a result, many researchers have observed that teachers, in science classrooms, do not lecture much (e.g. Hutchison and Hammer, 2010; Lin, 2006b). However, moments of monologues do still happen, for instance when the teacher is explaining a point, telling a story, summarizing, or giving a student's question an extensive answer (Lemke, 1990). According to Lemke, the exposition of logical arguments that requires the sequencing of logical connections, or narratives that use anecdotes, little stories or extended analogies need to be relatively long to produce the cognitive or even the emotional results they are meant to. Along the same line, Dalton-Puffer (2007) observes that the cognitive complexity of relationships between concepts and facts sometimes needs an explicit and linguistically coherent exposition that only a monologue can guarantee. In addition, Dalton-Puffer's interest in CLIL classrooms brings her to remark that from a language-related perspective, "the virtual absence of longer and syntactically complex teacher utterances (informative speech acts) means a considerable impoverishment of the linguistic input available to the learners" (2007, p. 91).

Overall, it appears that monologues are not inherently bad or good, but it all depends on how often and how effectively they are used (Dalton-Puffer, 2007).

So far, empirical studies conducted in CLIL classrooms and focused on examining the distribution of typologies of discourse were mainly directed to examining language use and language development (e.g. Dalton-Puffer, 2007). How teacher's monologic talk in bilingual settings can contribute to content (science) development has not been examined yet.

3.5.3 Peer Talk in the Science Classroom

Research into peer talk in science education that dates back to the 1970s (Barnes and Todd, 1977) reveals general positive effects, which have been confirmed by more recent studies (e.g. Blum-Kulka and Snow, 2004; Cazden, 2001; Mercer, 2000; Mercer and Littleton, 2007). Engaging in student-to-student discussions is beneficial to cognitive development as thoughts and ideas can roam freely and nurture higher order thinking (Cazden, 2001). In addition, it has been suggested that talking to peers teaches students to hone some social skills—such as constructing a shared understanding—that are necessary to become active members of a community (Blum-Kulka and Snow, 2004). Mercer describes the process of thinking together through interaction with the word *interthinking* (Mercer, 2000). Luft (2014) even encourages the use of new technologies such as videoconferencing as a learning strategy to teach students to "develop critical speaking and language skills, and to create knowledge".

Realistically, Dawes (2004) argues that working with peers does not automatically translates into productive communication and that learners need to be actually trained to acquire sensible strategies for listening and speaking to one another, and to agree and disagree in effective ways. In addition, Johnston (2009) highlights how teacher's choices (such as type and length of task, groups size) and actions (e.g. stating objectives, roles assigning, monitoring, checking, testing) are crucial for making peer learning work. As Cazden and Beck (2003) point out, the success of peer interactions is influenced by many contextual factors. Dysfunctional peer groups cannot only be dismissed as the result of behavioural issues. Some students revert to talk off-topic because the task at hand is too demanding and they are at the limit of their understanding. For some students, the social demand of talking in peer groups is too high (Galton and Williamson, 2003).

In CLIL classrooms—as the ones in this study—the language spoken when working in pair or group may be a limiting factor for the communication. Dalton-Puffer (2007) reports that in pair or group work situations, Austrian students invariably switch to German. This is different from what observed in Finnish schools, where students stick to English, probably because of the different role that English plays in the two societies (Dalton-Puffer and Nikula, 2006).

The focus of this study is mainly on whole classroom discourse and in particular on (a) how whole classroom interactions promote science learning and on (b) how teaching discourse practices promote science learning. Even if the focus is not on peer talk, its presence and function in the classroom in relation to the research focus is acknowledged.

3.6 Science Classroom Discourse Functions

In general, the level of analysis of the studies on science classroom discourse so far examined is not sophisticated enough to interpret the scientific meaning of classroom talk (Tang, 2017). This is where social semiotics (Halliday, 1978) comes in useful (as in Lemke, 1990). Within a social semiotic perspective, classroom discourse is explained as a meaning-making practice that the members of the classroom use for representing and understanding their world. According to the analytical framework proposed by Halliday and Matthiessen (2004), language has three functions: (a) *ideational* (for building and communicating thematic content), (b) *interpersonal* (for interacting), and (c) *textual* (for connecting and coordinating parts of text within a conversation). As the focus of this study is on how opportunities for learning science are supported by classroom discourse, this study is interested in exploring the ideational function of discourse, meaning the use of discourse for building disciplinary content. In particular, the next sections (from 3.6.1 to 3.6.4) are interested in reviewing how the ideational function of questions in science education has been researched and what outcomes have been emerging. This literature review gives also theoretical authority to the methodological decisions of this study, in terms of what sources of data need to be collected and how they are best analysed. In addition, these sections of the review contribute to justifying how the findings of this study are understood and interpreted and how conclusions can be conceptualized in order to contribute to knowledge.

3.6.1 Teacher's Questioning

Questioning dominates the science classroom talk (Dillon, 1988). For instance, Boyd and Rubin (2002) found that questioning, in primary classrooms with ELLs, is the dominant communicative function of teacher talk, representing more than half of all teacher utterances.

From a constructivist-cognitive perspective, questioning in science classroom has been examined for understanding how it helps construct meaning-making (DePierro, Garafalo and Toomey, 2003), supports inquiry teaching (Kawalkar and Vijapurkar, 2013) or how it fosters conceptual change (Yip, 2004). From a sociocultural perspective, questioning has attracted scholars' attention for its potential to shape learning spaces (Carlsen, 1987, 1991; Roth, 1996). A great deal of past research also focused on how questions are embedded in the classroom talk and how they shape the talk pattern itself, i.e. the IRE or IRF dialogue (e.g. Lemke, 1990).

Questioning usually follows a particular pattern of interaction, i.e. the IRF sequence. The first move of the IRF sequence is the initiation, or the teacher asking a question. Often, teachers ask further questions after the student's response, turning the third move, the feedback move, into another question. In this way, questions are a tool for further probing students, challenging or checking understanding. Thus, questions serve many functions: they are used to initiate and control the classroom dialogue (Sahin, Bullock and Stables, 2002), but also to extend and probe students' thinking (e.g. Elder and Paul, 1998; Ong, Hart and Chen, 2016; Paul and Elder, 2007). Furthermore, Andersson-Bakken and Klette (2016) provide evidence of how teachers' questions in L1 science classrooms are mostly meant to assess the students' knowledge and to check comprehension of specific conceptual terms.

By adapting Ernst's (1994) functional analysis of students' and teachers' utterances, Boyd and Rubin (2006) found that a teacher's top three communicative functions in classrooms with ELLs are display questions, followed by authentic questions, and clarification requests. Display questions are meant to check retention of previous knowledge or to recall previously stated information (Ernst-Slavit and Pratt, 2017). Questions are authentic when the teacher does not know the answer in advance. In the science classroom they can be used as a means of initiating inquiry-based learning (Roth, 1996). Clarification questions build on previous utterances by asking for an explanation or a redefinition of what has been said. As display questions ask students to recite pieces of knowledge that the teacher already knows, these questions have often been associated with forms of rote learning and teachers have been encouraged to avoid them, both in L1 classrooms (e.g. Alvermann and Phelps, 1998; Vacca, Vacca and Mraz, 2005) and in L2 classrooms (e.g. Peregoy, Boyle and Cadiero-Kaplan, 2013). By contrast, authentic questions ask students to present their own thinking, be it an evaluation, an interpretation or a genuine creation. They are assumed to be the gateway to meaningful learning and to discussion as "the essence of the *question* is to open up possibilities and keep them open" (Gadamer, 2004, p. 298). These assumptions have been challenged by some recent research that suggests that some degree of teacher control over talk through structured questioning (for instance by probing) can indeed encourage collaboration and reasoning (Wilkinson, Murphy and Soter, 2003) and help keep students focused and engaged in deep discussion (Soter, Wilkinson, Murphy, Rudge, Reninger and Edwards, 2008). According to Boyd and Rubin (2006), teacher's questions can elicit elaborate talk not (only) as a consequence of their authenticity or open-endedness, but rather by virtue of their contingency, meaning the extent to which questions are responsive to students' contributions and builds on or extends from them. Chang-Wells and Wells (1992, p. 33) defined these questions as "contingently responsive". Contingent questioning has the potential to nurture talk itself by offering "opportunities for students [...] to initiate topics of discussion, to elaborate on their own responses, or to direct substantive questions to fellow students" (Boyd and Rubin, 2006, pp. 143-144). Similarly, in L1 science classrooms, Chin (2006, p. 1343) observed that when teachers build on students' earlier contributions they are able to "promote productive talk activity in students at a level beyond mere recall". Boyd *et al.* showed that teachers' non-authentic display questions can indeed promote student talk as long as they are contingent on students' utterances.

In science education, contingent questioning has been studied by van Zee and Minstrell (1997b, p. 227) who dubbed it *reflective toss*. In a *reflective toss* responsibility for thinking is "thrown" back to the students in the form of a request for clarification, for rationale or for verification. In line with this, Chin (2006) investigated questions imbedded in IRF teaching exchanges and proposed a *questioning-based discourse* analytical framework to investigate how teachers use questions in the science classroom and how this use can promote productive thinking. In particular, Chin (2006) revealed some recurrent patterns in the feedback/follow-up move. She discovered that to a student's correct response, a teacher could either affirm the answer and then move on to lecturing with direct instruction or accept the answer and then ask another related question or series of questions that build on the previous ones by probing or extending. By contrast, when a student's answer is incorrect the teacher either explicitly corrects it or challenges the students with another question. Another common feature observed by Chin (2006) is that teachers frequently restate or reformulates students' answers as a form of both affirmation and amplification for the whole classroom (cf. Chapin, O'Connor and Anderson, 2009). Chin's conclusion (2006) is that teachers do indeed orchestrate classroom discourse and therefore shape students' learning and that a responsive approach to the feedback move is a key element to promoting higher-order thinking skills. This conclusion is very similar to the one drawn by Boyd *et al*. (2006) while observing English language learners (ELLs) classrooms at primary level.

In addition to all this, Chin (2007) observed that not only does effective teacher questioning stimulate and support students to verbalize their ideas, but it also provides peer students with opportunities to vicariously learn from others' interventions, which confirms Bandura's sociocognitive theory of learning (Bandura, 1986).

To conclude, research has so far highlighted how teacher's questions dominate classroom discourse in general and how these questions shape science learning in classroom conversations. However, to date, no study in science education has closely looked at teacher questioning as a tool for promoting science understanding in bilingual settings. For instance, little is known about how science conceptual understanding is promoted through questioning practices or how science language develops and is practiced through questioning when the medium of instruction is a foreign language. Answering these questions would generate important understanding about how opportunities for learning science are supported in CLIL settings.

3.6.2 Students' questioning

Students also ask questions. Purportedly, students' questions are at the heart of scientific inquiry (Chin and Brown, 2002). Students questions enhance understanding (Van Zee, Iwasyk, Kurose, Simpson and Wild, 2001) and support them to become autonomous learners (Etkina, 2000). Students questions also allow teachers to identify misunderstandings and/or difficulties and to better respond to students' needs (Harper, Etkina and Lin, 2003; Watts, Gould and Alsop, 1997). However, classroom-based research suggests that, despite their benefits, "student questions are very infrequent and unsophisticated" (Graesser and Person, 1994, p. 105).

Chin and Brown (2002, p. 524) broadly distinguish two types of students' questions: basic information questions (reserved to factual and procedural questions) and wonderment questions (pitched at a conceptually higher level). The latter are asked when students try to integrate and connect new knowledge with existing knowledge. Because they mirror an effort to understand and "reflect curiosity, puzzlement, scepticism or a knowledge-based speculation", wonderment questions greatly promote conceptual understanding.

Many factors have been identified to enhance or constraint students' questioning in the science classroom. For instance, Chin and Brown (2002) found that problem-solving activities tend to elicit questions from the students; Krystyniak and Heikkinen (2007) reported that inquiry-based laboratory settings are also conducive to generating questions, many of these peer-directed. In terms of dialogue stream, Lemke (1990) observed that when a student asks a question and the teacher answers it this is felt as an invitation for other students to also ask their questions. This generates a particular type of dialogue that Lemke dubbed *Student-Questioning Dialogue*. Van Zee *et al.* (2001) found that students' questioning is enhanced by both a comfortable discursive environment supported by elicitation moves from the teacher and some degree of familiarity with the topic. Many authors consider the social factor as crucial in pushing students to ask questions, because students need to feel secure before exposing themselves (Watts *et al.*, 1997). In L2 classrooms, like the ones analysed in this study, using an imperfectly known language to ask questions might further limit students' unsolicited interventions, as the weaker learners might feel even more vulnerable and exposed. In these classrooms, the most prevalent types of questions initiated by students are non-understanding claims and requests for explanation, confirmation and clarification (Markee, 2015). In L2 classrooms, a barrier to epistemic access is not only conceptual in nature but it may also be linguistic (Kääntä and Kasper, 2018). Therefore, students' questions may indicate not only conceptual non-understanding but also a gap in their L2 lexicon. Dalton-Puffer (2007, p. 103) investigated students' questions in CLIL classrooms (not specifically in science classrooms) and found that most of the questions that CLIL students ask are vocabulary-related and that what she calls "real content questions" occur "very sporadically".

Even though students' questions are crucial for scientific inquiry, this review has revealed that, to date, there have not been studies in science education about students' questions in bilingual (CLIL) classrooms. How students take agency over their own learning and actively question the materials they are presented with through a foreign language has not been investigated yet. This study will contribute to answer these questions.

3.6.3 Sensemaking and Science Classroom Discourse

Among the functions of science classroom discourse that promote knowledge building is *sensemaking*. In this study, the term *sensemaking* is preferred to *meaning-making*, as the latter also represents a notion that is central to sociocultural theories of second language acquisition (SLA): "[l]anguage's power resides […] in its use value—its meaning-making capacity" (Lantolf, 2011, p. 25). Accordingly, quite a few CLIL studies (e.g. Meyer, Coyle, Halbach, Schuck and Ting, 2015) have examined this construct and the related notion of *meaning negotiation* also in relation to science education (for instance, Evnitskaya and Morton, 2011; Moore and Dooly, 2010). However, these studies are mostly focused on second/foreign language learning and are theoretically framed within a sociocultural perspective of language learning instead of looking at learning through a science education perspective (see section 2.12.3).

In science education research, the concept of *sensemaking* has been applied with a certain consistency only since 2007 (Odden and Russ, 2019). Although sensemaking is an intuitive concept, there has, so far, been little agreement about how to theoretically frame and consequently define it. For instance, the issue has been approached from both sociocultural (e.g. Ford, 2012; Warren, Ballenger, Ogonowski, Rosebery and Hudicourt-Barnes, 2001) and cognitive perspectives (as in Kapon, 2017). Consequently, it has been framed either as a discourse practice or as a cognitive process. Recently, Odden and Russ (2019, pp. 191-192) proposed that:

> *sensemaking* is a dynamic process of building or revising an explanation in order to 'figure something out'—to ascertain the mechanism underlying a phenomenon in order to resolve a gap or inconsistency in one's understanding.

This is the definition that this study will refer to when dealing with sensemaking. Also, this study takes a stance in favour of sensemaking as a discourse practice.

As for the importance of sensemaking in science education, many authors have contributed with different arguments. For instance, Chin and Brown (2000) argue that sensemaking promotes deep learning and connections-making, Kapon and diSessa (2012) note that it facilitates the application of knowledge to new situations; Feynman (1999) points out how school science comes closer to what scientists actually do when students are engaged in making sense.

How students *make sense* in the science classroom is a complex process, that Odden and Russ (2019, p. 192) synthetize as a sequence of steps, that starts with the identification of a gap, goes through the "shopping for related ideas", and ends with "piecing them together into [a] coherent explanation". The general goal of this process is for students to figure things out for themselves with the guidance of the teacher (Dewey, 1997).

While referring to generic CLIL classrooms (not specifically science classrooms) Dalton-Puffer (2007, p. 67) considers meaning-making in the CLIL discourse as one of the "cornerstones" of content development and argues that "it would be a promising and worthwhile undertaking to study more closely how school subjects are 'talked into being' in classrooms" (Dalton-Puffer, 2007, p. 90). Up to now, there has been little research on sensemaking in bilingual science classrooms. However, an insightful exception to this could be represented by some studies that conceptualize the everyday sensemaking practices of culturally and linguistically diverse students as intellectual resources in science learning (e.g. Brown *et al.*, 2005; Warren *et al.*, 2001). Apart from these, there has been virtually no study in science education focused on sensemaking as a discourse practice in CLIL classrooms. Little is known about how bilingual students *figure things out* and develop conceptual understanding while engaged in classroom conversations.

3.6.4 Metadiscourse in the Science Classroom

As mentioned above, in the functional analysis of discourse proposed by Halliday and Matthiessen (2004), language has also non-ideational purposes (i.e. textual and interpersonal functions), with which metadiscourse is concerned. Metadiscourse, also termed meta-talk by Schiffrin (1980) and commonly summed up as "discourse about discourse", is defined by Hyland (1998, p. 437) as one of "those aspects of the text which explicitly refer to the organisation of the discourse or the author's stance towards either its content or the reader". Its purpose is to direct the readers or the listeners rather than inform, so that they will know how to interpret the author (Crismore, 1983).

Metadiscourse is ubiquitous in any communication and it has been researched in a wide range of texts, science discourse included (Crismore and Farnsworth, 1990). Recently, metadiscourse has been the focus of attention of studies conducted in L1 science classrooms (Tang, 2017), language classrooms (Amiryousefi and Rasekh, 2010), and, in science education, with English language learners classrooms (Msimanga and Erduran, 2018). Even though some studies conclude that most metadiscourse markers are basically redundant and unnecessary (e.g. Sloan, 1984), other findings tend to agree that they do play a facilitating role as an effective technique for improving comprehension. In particular, Pérez and Macià (2002) showed how metadiscourse items facilitate listening and comprehension for second language learners. In their study, a positive effect of metadiscourse items appeared to be inversely related to the students' level of proficiency in English. In other words, metadiscourse seems to help learners with a lower level of English. In a study conducted in South African upper secondary classrooms with English language learners, Msimanga and

Erduran (2018) were able to demonstrate that teachers' use of metadiscourse mediates science conceptual understanding in argumentation activities. So far, Msimanga and Erduran's study is the only one that addresses metadiscourse in bilingual science classrooms with the purpose of investigating science understanding. How metadiscourse contributes to science learning in bilingual (CLIL) classroom discourse outside argumentation activities has not yet been investigated. In particular, little is known about how teacher's metadiscourse facilitates conceptual understanding and supports science language development during classroom conversations when the medium of instruction is a foreign language.

3.7 Theoretical framework

This final section of the chapter presents the theoretical framework adopted in this study for investigating science learning opportunities in a CLIL setting. Also, this section theoretically bridges the literature reviewed in this Chapter and in the previous Chapter 2 with the methods and methodologies that are presented in the next chapter. The literature review so far conducted has identified and clarified the knowledge gap in the existing research relevant for this project. The next section identifies the conceptual lenses through which the research will look at and explore that gap.

3.7.1 Significant Contribution of the Theoretical Framework

It is important to note that the theoretical framework presented here is distinctive in that it draws on and combines a number of different models, concepts and theories. Its multiple purposes are to support and inform the research, to set conceptual boundaries to it, to help design it —together with the research questions —and to provide a system of reference for limiting the scope and making sense of the data.

A graphic representation is provided in Figure 3.1. The diagram visually explains how and to what extent four theoretical perspectives (referred here as *components*) are conceptually linked for the purpose of this study. Essentially, this study draws upon a sociocultural approach applied to science education (component A), with a focus on language and discursive practices employed for promoting participatory learning (component B), informed by cognitive theories of bilingual education (component C), and consistent with an orientation of language-as-resource (component D).

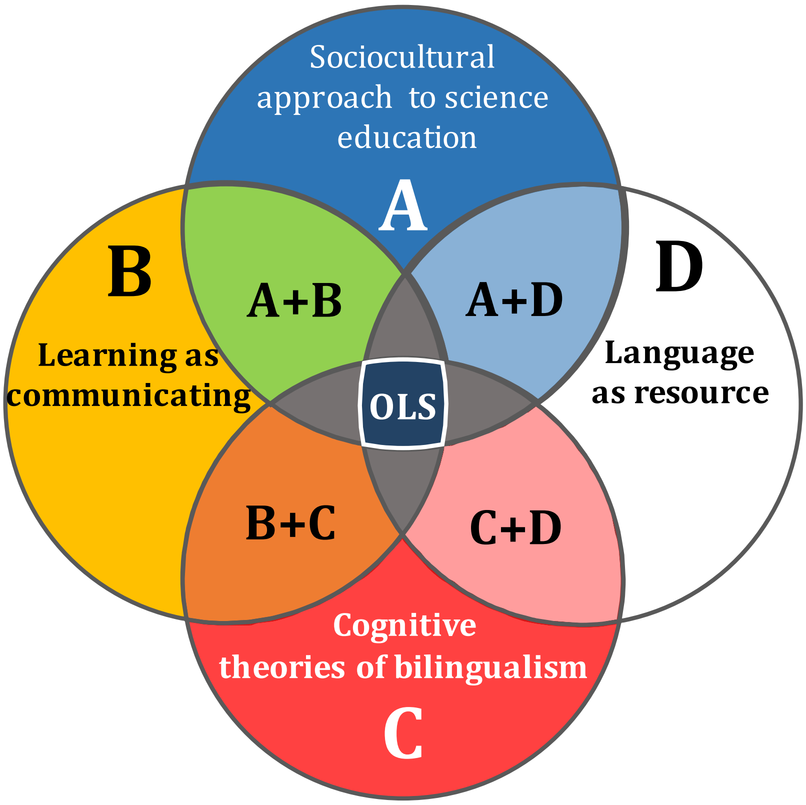

Figure 3.1 Theoretical framework representation. OLS, i.e. Opportunities for Learning Science, are at the core of the diagram.

The intersection area between these four components (A+B+C+D) theoretically defines this study, meaning that the study is framed by an emergent combination of them. This intersection is represented by the Opportunities for Learning Science (OLS).

In the next sections, these components are discussed both individually and jointly with reference to their contribution to the investigation. These components are also outlined in Table 3.1. Chapter 4, section 4.4 it examines how these conceptual components influence research design and analysis.

Table 3.1 Main theoretical components and theoretical constructs.

Framework Components	Main Theoretical components	Key references	Theoretical constructs
A	***Science Education in Sociocultural Theories***	Vygotsky (1978) Tharp and Gallimore (1988)	Cognitive development stems from social interactions.
		Rogoff (1998)	Learning is collaborative.
		Bruner (1978)	Learning occurs in the ZPD.
		Greeno (1998)	Science learning emerges from participation in situated social practices
A + B		Lemke (1990)	Learning science as learning the social language of science
B	***Learning as communicating***	Vygotsky (1986)	Cognitive development is mediated by language.
		Sfard (2008)	Thinking as Communicating (Commognition)
		Cazden (2001)	Classroom Discourse
		Halliday (1993)	Language-based theory of Learning
		Bandura (1986)	Sociocognitive theory of learning
B + C		Cummins (1980)	CALP and BICS
		Schleppegrell (2004)	The language of schooling
C	***Cognitive theories on bilingualism***	Cummins (1979)	Developmental Interdependence Hypothesis
		Cummins (2000)	Common Underlying Proficiency (CUP)
C + D		García (2009)	Heteroglossic ideology of bilingualism
D	***Language-as-resource***	Ruíz, (1984)	Language-as-resource
		Tollefson (1999)	Language beliefs affect language education
D + A		Moschkovich (2002)	A situated and sociocultural perspective on bilingual mathematics learners
		Planas and Setati-Phakeng (2014)	
		Ní Ríordáin (2018)	
OSL	***Opportunities for learning science (this study)***	Stevens (1993) Gee (2008)	Opportunity to learn (OTL)

3.7.2 Component A: Sociocultural Approach to Learning

This study adopts a sociocultural perspective to learning. This perspective is rooted in the work by Lev Vygotsky (1978), which examined how children learn from their participation with other people in activities. In classroom settings learning is facilitated by the process of guided participation (Rogoff, 1990), meaning that a child learns in social activities when assisted by a more experienced other. Within this perspective, the construction of science knowledge is a collective practice (Roth and Lee, 2002; Tobin, 2012), is situated in social contexts (Sadler, 2009) and mediated by social interactions (Scott, 1996; Solomon, 1987; Tharp and Gallimore, 1988). Within a sociocultural model of teaching and learning science:

a) students are portrayed as participant in *communities of practice* (e.g. in Moje *et al.*, 2001);

b) students learn science through participation in joint activities (Rogoff, 1998; Tharp and Gallimore, 1988) when they develop community-specific *Discourses* (Gee, 2005), meaning that they are able to speak the language of science and share values and social norms that allow them to get access to the epistemic practices of science (Kelly and Licona, 2018);

c) students are situated in specific environments, or contexts (Greeno, 1998), that are formed by the learners themselves, other participants, ideas, tools and physical resources and which effect what learners can do and come to learn (Sadler, 2009);

d) CLIL students learn science in a large Zone of Proximal Development, or ZPD (Jäppinen, 2005) where they need a great deal of scaffolding (Bruner, 1978).

The concept of *communities of practice* (CoP) mainly draws upon the work by Lave and Wenger (1991). Wenger (2011, p. 1) defines communities of practice as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly". An important aspect of a CoP is the shared repertoire of resources, such as a common language, a common culture, same shared values, goals and norms that allows the members to communicate efficiently and insightfully (Wenger, McDermott and Snyder, 2002). Despite the rhetoric of science learning as a collective practice, results from classroom research show that students are rarely exposed to CoP and therefore teachers have to translate these "cultural pieces" from their own experience to the students while teaching both content and practices (Davidson and Hughes, 2018, p. 1287). Moreover, CoP as presented by Lave and Wenger does not address unequal participatory opportunities (Haneda, 2006). For instance, in bilingual content classrooms, the linguistic challenges that students have to face make the issue of equal opportunities to participate quite relevant.

In this study, classroom discourse is analysed through many foci, and CoP is one of these, even though a peripheral one. In particular, CoP is here relevant for its potential of interpreting the development of science language as the appropriation of a shared language code which brings students closer to how scientists speak.

Furthermore, the sociocultural perspective that frames this study also draws upon the Vygotskian construct of Zone of Proximal Development, or ZPD (Brown, Ellery and Campione, 1997; Campione, Brown, Ferrara and Bryant, 1984; Vygotsky, 1978; Wertsch and Rogoff, 1984). ZPD is the difference between what a learner can do without support and what he or she can do with support provided. Vygotsky's construct of ZPD has been often productively applied in second language learning research (Ohta, 2005) and in research on bilingualism (Cummins, 2000, 2001). Typically, bilingual settings are characterised by a larger ZPD (Jäppinen, 2005, 2006), meaning that, in order to reach the upper limit of their learning potential, bilingual students need a great deal of support from (especially) their teachers in terms of *scaffolding*. The metaphor of scaffolding (Bruner, 1978) represents the "temporary assistance that teachers provide for their students to assist them to complete a task or develop new understandings, so that they will later be able to complete similar tasks alone" (Hammond and Gibbons, 2005, p. 9). Scaffolding takes many forms, such as an intense use of visuals, gestures, and special use of the spoken language that facilitate linguistic and conceptual understanding, which are investigated in this study. The concepts of ZPD and scaffolding are not only popular in bilingual education but also in science education (e.g. by Scott, 1998).

The adoption of a sociocultural lens to investigate the phenomenon of science learning in CLIL settings is consistent with the researcher's choice to focus on processes such as discourse practices instead of on products (i.e. academic achievements), and to adopt a methodology and a research design that take both individuals (with their beliefs and perceptions) and their sociocultural learning environment into consideration.

3.7.3 Component B: Learning as Communicating

The second theoretical lens that underpins the present framework is provided by Cazden's work on classroom discourse (Cazden, 2001) and Sfard's "communicational approach to cognition" (2001, p. 22). Cazden (2001) provides a framework for explaining how learning occurs in classroom discourse. Sfard (2008) argues that interpersonal communication and cognitive processes are complementary processes. This idea is rooted in Vygotsky's (1986) rejection of the dichotomy of thought and language—as learning is *mediated* by language—and is summed up by Sfard's construct of *commognition*, a combination of *communication* and *cognition* (2001). The author conceptualized commognition in the field of mathematics education, but for the purpose of this study, her idea has been adapted and transferred to science education. This construct also contributes to foregrounding language and classroom discourse in the teaching and learning processes, which are both important in this study. This component of the theoretical framework is also informed by Lemke's seminal work *Talking Science* (1990), which manages to link classroom talk to both cognitive and social aspects. Another important contribution to frame this aspect is provided by Halliday's language-based theory of learning (Halliday, 1993).

Finally, I've also included Bandura's sociocognitive theory (Bandura, 1977). Sociocognitive theory posits that vicarious learning in social contexts can occur when students observe and replicate effective strategies (such as problem-solving strategies and deductive reasoning) verbally modelled by their classroom peers, who act as cognitive models (Bandura, 1986, 1989). This is relevant to this study because when students verbalize in the CLIL science classroom, they provide opportunities for vicarious learning to occur (Chin, 2007). Bandura's theory further complements the notion of learning as communicating in the sense that students also learn by listening to their peers.

These authors, each from their own disciplinary perspectives and in complementary ways, made a significant contribution to the conceptual framework of this study. Bringing their thoughts in the conceptual framework provides a theoretical lens for conceptualizing, analysing and interpreting learning as a discursive process.

3.7.4 Intersection A+B

At the intersection area A+B between the sociocultural approach to science education (A) and a communicative approach to learning (B), there are sociolinguistic works applied to science education with a focus on discourse and language. These works examine how teachers and students construct meaning through classroom interactions and how learners develop the classroom language of science that allows them to academically interact. The most relevant of these works for the present research study is *Talking Science* by Lemke (1990). In this study, Lemke's work is used as a reference for analysing and discussing classroom discourse. In particular, Lemke's conceptualization of thematic patterns is implemented in interpreting observational data (Chapter 5). Finally, Lemke's *Talking Science* is also the most cited work in this study.

3.7.5 Component C: Cognitive Theories of Bilingual Education

The third component that frames this study is represented by Cummins' cognitive theories of bilingualism, and specifically the developmental interdependence hypothesis (Cummins, 1979) and the Common Underlying Proficiency model (Cummins, 1980), which were further explored in Chapter 2, section 2.2. Adopting a cognitive approach to bilingualism may seem at odds with framing learning within a sociocultural perspective. However, a cognitive view of bilingualism is here consistent with the adoption of a language-as-resource orientation (component D of this framework, section 3.7.7).

3.7.6 Intersection B + C

At the B+C intersection area, between the Learning as Communicating approach (B) and cognitive theories of bilingualism (C), there are theories and models that link a participatory approach to learning with a special focus on language to cognitive theories in bilingual education. In this area, concepts such as the distinction between CALP/BICS (Cummins, 1979; Cummins, 1980) and academic language (Schleppegrell, 2004) find their place. These concepts were further explored in section 2.3. Learning the academic language of science and its registers is a requirement for academic success. Therefore, when academic language explicitly appears in the CLIL science classroom opportunities for learning science potentially arise.

3.7.7 Component D: Language-as-Resource Orientation

The theoretical framework implemented in this study is completed by a fourth theoretical construct, i.e. language-as-resource. This orientation to language was first theorized by Ruíz (1984). Ruiz explains that a language orientation is a "complex of disposition toward language and its role" (1984, p. 16). In particular, Ruiz model illustrates how a language can be viewed as a problem to be solved, as a resource to be utilized or as a right to be established or preserved. Ruiz conceptualizes the orientation of language-as-resource in response to the conceptualisation of language as a liability or as a barrier. This latter orientation to language has been fuelled by many studies that evidenced achievement gaps when English language learners (ELLs) were concerned (e.g. in Buxton and Lee, 2014; Lacelle-Peterson and Rivera, 1994; Short, 2000). Recently, it has been suggested that the academic achievements of many ELLs may improve by changing how schools and societies regard languages and what teachers consider appropriate for the classroom (Flores and Rosa, 2015). These considerations can also be extended to bilingual contexts in general and even to L1 science classrooms, where academic language (and science language, as explained in section 3.4) may represent a barrier for students. When adopting a language-as-resource orientation, languages are regarded as “potential resources for gaining access to particular spaces and sorts of capital” (Planas and Setati-Phakeng, 2014 p. 886). Within this conceptualization, the use of multiple languages is encouraged for its “potential for thinking and doing” (Planas and Civil, 2013, p. 363) as it allows practitioners to capitalize on the benefits of bilingualism and to maximize the generation and exploitation of learning opportunities (Ní Ríordáin, 2018). In this sense, translanguaging practices—i.e. the fluid interweaving of repertoires of more than one language—become particularly valuable (Garcia and Wei, 2013). Hence, the conceptualization of language-as-resource and the notion of translanguaging are often tightly linked.

A teacher’s language orientation has profound teaching implications. Researchers concerned with critical linguistics have recognised how “implicit assumptions” about language and language learning impact teaching practices (Tollefson, 1999, p. 43). This is not meant in the sense of the Sapir-Whorf hypothesis—meaning that language determines how we perceive the world—but instead in the sense that our behaviours and experiences are shaped by our beliefs. In particular, the connection between language beliefs and teaching practices is based on Tollefson’s theory (1999, p. 43) that our language beliefs “determine our reality of language classrooms”, which includes students, teachers, topics and pedagogies. For example, a standard language ideology posits that languages are uniform and uniformity to standards represents both the teaching goal and how academic success is measured (Milroy, 2001).

The interest in language-as-resource primarily developed within bi-/multi-lingual classroom research with a penchant for mathematics education (e.g. Barwell, 2018; Planas and Civil, 2013; Setati, Molefe and Langa, 2008). In science education research, the construct of language-as-resource is less popular but nevertheless present, even if not explicitly. For instance, Warren *et al.* (2001, p. 548) argue that reconsidering what counts as science and what counts as students’ culture (and language) may help develop better teaching practices “that build on diversity as an intellectual resource rather than a problem or tension in science learning.”

The only example in science education that explicitly addresses the dichotomy of language-as-resource and language-as-problem is a recent study where the dichotomy was applied in terms of *language-inclusive* and *language-exclusive* ideologies to teachers’ approach to summative assessment of classes with ELLs (Lemmi, Brown, Wild, Zummo and Sedlacek, 2019). This study examined science classrooms where English language learners (ELLs) were also present and concluded that teachers adopt either a language-inclusive ideology (i.e. a language-as-resource approach) or a language-exclusive ideology. In Lemmi *et al.*'s work (2019, p. 1) a language-inclusive ideology indicates that multiple forms of language are acceptable in a science classroom, whereas a language-exclusive ideology implies that "certain forms of language are expected in a science class, and others are not appropriate". The scarcity of studies that refer to language-as-resource in science education—Lemmi *et al.*'s work, 2019, is the first and only one to my knowledge—indicates a clear knowledge gap. For instance, very little is known about what the potential of such an orientation to language might be for promoting science learning in CLIL classrooms. Also, very little is known about how CLIL science teachers' orientations towards language influence classroom discourse practices in general and translanguaging practices in particular. These are questions that this study may contribute to answering.

3.7.8 Intersection C+D

At the C+D intersection area, between Bilingual Education theories (C) and the conceptualization of language-as-resource (D), there are the studies of those authors who praise heteroglossic ideologies of bilingualism over monoglossic ideologies (e.g. García, 2009). Monoglossic ideologies of bilingual education consider the child's two languages as separate and autonomous systems. A heteroglossic ideology view multiple language practices as in interrelationship. As a consequence, favouring heteroglossic ideologies means supporting translanguaging practices, i.e. the flexible and alternating language use of bilinguals (García, 2009). This orientation to language in bilingual settings was further examined in section 2.6. This conceptualization draws upon Cummins' theory of linguistic interdependence (Cummins, 2008a) and provides foundation for interpreting and discussing the observational data of this study (Chapter 6).

3.7.9 Intersection D+A

The intersection area between D (i.e. language-as-resource conceptualization) and A (i.e. a sociocultural perspective of science education) is represented by the works of those authors who adopted a sociocultural perspective to describe how students rather than struggling with the differences between the everyday and the science registers or between L1 and L2, use resources from both registers and languages to communicate scientifically. This intersection area is populated by studies in mathematics education conducted by Moschkovich (2002), Planas (2014) Planas and Setati (2009) and Ní Ríordáin (2018).

3.7.10 Opportunities for learning science (OLS)

The intersection area between all the aforementioned components (A, B, C and D) theoretically defines this study. At this core intersection, there is the concept of *opportunities for learning science*, conceptualized within a situated sociocultural dimension of learning (i.e. component A), when communication is central to learning (i.e. component B) and when learners are using a foreign language (i.e. component C) that is considered as a resource like any other language they use (i.e. component D).

Science education is not only a matter of what science content, values and epistemologies are selected and how these are taught. For science education to be effective it must also reach the students. In order to learn, children need to make sense of the information they are presented with (e.g. an explanation, a question, a problem, a diagram). This complex nature of education is captured by the construct of *opportunities for learning*.

The general concept of *opportunity to learn* (OTL) or *opportunity for learning* dates back to Carroll's model of learning (Carroll, 1963; Carroll, 1977). In its original version, OTL was simply "the amount of time permitted by the instructional system for learning" (Carroll, 1977, p. 156). In other words, according to Carroll, school learning is dependent on the time students spend engaged in learning. However, Carroll was aware that a more complex interaction of factors was at work in affecting individual opportunities to learn. His data indicated that quality of instruction, aptitude and "ability to understand instruction"—an independent variable, in Carroll's data—affected opportunities to learn. Stevens (1993) conceptually frames the OTL concept within four variables: (a) content *coverage* (of the core curriculum), (b) exposure (i.e. time allocated and depth of teaching), (c) emphasis (placed on specific learning goals and topics) and (d) quality of instructional practices. The latter includes, for instance, the kinds of tasks posed, of questions asked and responses accepted, the nature of the discussions (Hiebert and Grouws, 2007, p. 379).

Gee (2008) criticizes this traditional view of opportunity to learn as incomplete and offers an alternative sociocultural perspective to opportunity. In particular, Gee observes that if the input the teacher offers is not processed by the learner (not paid attention to and used) it has no effect. Gee (2008, pp. 79-80) offers some reasons why an input may not effectively reach the learner (e.g. prior knowledge and learners' resistance to intake for cultural, social or emotional reasons). In bilingual settings, language may also be a reason why an input does not reach the learner. Before Gee, in science education research, also Tuyay, Jennings and Dixon

(1995, p. 76) considered opportunity to learn "beyond the unidirectional presentation of information", meaning that opportunity to learn is not a one-way construct, i.e. from teacher to students. Similarly, in geometry classes, Lipowsky, Rakoczy, Pauli, Drollinger-Vetter, Klieme and Reusser (2009) note that opportunity to learn must be perceived and utilised by student in order to be effective.

Since its introduction, the concept of *opportunity to learn* has played an important role as an indicator of educational effectiveness and educational fairness by evaluating the alignment between learning goals, instruction and assessment (e.g. Gee, 2003; Herman, 2015; Porter, 2002; Webb, 2007), with a focus on economically, socially and/or culturally disadvantaged children (e.g. Abedi and Herman, 2010; Stevens, 1993, 1996; Wang and Goldschmidt, 1999). Stevens' framework of OTL revolves around the ethical and moral need to fight a "pedagogy of poverty", which she describes as "one that reduces or denies […] students the opportunity to learn the core curriculum for their age or grade level" (Stevens, 1993, p. 232). This description is disquietly close to the risk Dalton-Puffer (2008, p. 143) mentions about content learning in CLIL contexts, namely the "reduced subject learning" as a result of imperfect understanding and simplified content (Hajer, 2000).

OTL have been often examined in relation to mathematics education and ELLs (e.g. in Civil, 2012; Takeuchi, 2016). By contrast, the interest of science education in this construct has been more sporadic. In one of the few studies explicitly focused on opportunities for learning in science education, Tate (2001) examines them in terms of civil rights. Rosenthal (1996) generically acknowledges the linguistic difficulties of non-native English students in science education without specifically examining the construct. Lee and Buxton (2008) link opportunities for learning science to the lack of exposure to proper science instruction that minority-language students experience when removed from the science classroom to receive English language instruction. Lee and Buxton (2008) also explore opportunities for learning science in terms of how high quality resources and meaningful hands-on activities are equally or unequally distributed. In an ethnographic study concerned with opportunities for students to learn scientific inquiry, Kelly and Breton (2001) examine how access to science knowledge is built through social interactions in elementary bilingual classroom.

Overall, even if frequently mentioned, only occasionally are opportunities for learning science adopted as a conceptual construct. An example is the ethnographic study by Tuyay *et al.* (1995) that investigates how opportunities for learning science become visible in classroom interactions in terms of students' meaning-making of written science texts they are asked to write. These considerations highlight the potential contribution to knowledge of a study in bilingual science education that investigates science learning from the theoretical perspective of opportunities for learning science.

In this study, opportunities for learning science (here also OLS) are conceived as an interactional phenomenon, framed within a situated sociocultural perspective of learning that posits that learning originates in social interactions (Vygotsky, 1978). In particular, for the specific purposes of this study, the notion of *opportunities for learning science* is defined as a combination of the degree to which students:

(a) build conceptual understanding of science content and processes,

(b) build understanding of science epistemologies and science values, and

(c) develop *science language*.

The proposed definition of opportunity to learn science is an adaptation to science learning in CLIL settings of the more general notion of *opportunity-to-learn* (OTL) as conceptualized by Stevens (1993) and extended by Gee (2003, 2008) within a sociocultural perspective.

The first two aspects (a and b) of the construct refer to what Duschl (2008, p. 279) proposes as a set of harmonized learning goals for science education. In particular, Duschl (2008, p. 279) recommends that science learning should focus on developing the following:

> the *conceptual* structures and *cognitive* processes used when reasoning scientifically, the *epistemic* frameworks used when developing and evaluating scientific knowledge, and the *social* processes and contexts that shape how knowledge is communicated, represented, argued, and debated.

In particular, 'conceptual understanding' is here understood as a meaningful (Ausubel, Novak and Hanesian, 1968) and socially mediated (Wertsch, 1991) way of learning. Traditionally, conceptual understanding has been framed by cognitive or socio-cognitive approaches to learning (see Treagust and Duit, 2008). In these traditions, conceptual understanding refers "to situations in which students are attempting to make sense of relatively large bodies of organized conceptual public knowledge or using the knowledge that they have internalized to generate explanations of their experiences in the world" (Pines and West, 1986, p. 584). In this study, conceptual understanding moves away from focusing on individuals' mental representations of scientific concepts and ideas (e.g. in Gabel, 2003) and embraces a socio-cultural perspective, which emphasizes the importance of context (Linell, 1998) and, in particular, of "the discursive and interactional aspects of human learning and understanding" (Furberg and Arnseth, 2009, p. 157). Within this perspective, social and cognitive processes are intertwined (Solomon, 1987; Vygotsky, 1978) and individual reasoning abilities and sensemaking originate from the dialogue with others (Wegerif, Mercer and Dawes, 1999).

The last aspect of the construct, i.e. *science language* development (c), has been chosen because relevant for the CLIL context this study investigates. Not only is science language necessary to get access to science, but it also poses specific challenges to students learning science through a second language (Richardson Bruna *et al.*, 2007).

3.7.11 Overview of the Theoretical Framework

The framework that emerged from the conceptual dimensions presented in the literature review of this thesis is that opportunities for learning science in a bilingual setting are a complex phenomenon conceptually framed by an original combination of different research traditions and which defines its own theoretical boundaries between sociocultural theories applied to science education, a conceptualization of learning through communication, cognitive theories of bilingualism and an orientation of language-as-resource. The presented model portrays four components that reflect their interdependency within the bilingual science classroom. While each component contributes to defining the conceptual boundaries of the study, it is only when all four components interact that the full complexity of the science CLIL environment—in terms of opportunities for learning science—can be understood and explained. In this study, the theoretical framework works as a unit, meaning that every part of the study is framed by the same combination of theoretical components. In particular, how the theoretical framework relates to the various research components of this study is described in the next chapter, section 4.4.

3.8 Conclusions

In summary, a review of the literature into science education indicates that school science is an evolving corpus of theories which has been shifting from focusing on the body of knowledge that traditionally constitutes science to examining how this knowledge is built (i.e. the Nature of Science). In this regard, it was highlighted that very little is known about how science nature and science values can be promoted and taught through classroom conversations in bilingual (CLIL) classrooms.

It was noted that the emphasis placed on the participatory nature of science knowledge building is transforming language into a topic of primary importance in science education and in science education research. Because this study explores science learning when students are using a foreign language as a medium of instruction, the role of language in science learning was explored in detail. In particular, the spoken language in the classroom, i.e. classroom discourse, was unpacked for explaining how it relates to opportunities for learning science. This literature analysis revealed quite a few specific knowledge gaps. In particular, so far, no study in science education has looked at teacher questioning for promoting science understanding in bilingual settings. In addition, very little research has been conducted to investigate how metadiscourse facilitates science learning in bilingual (CLIL) settings. Similarly, sensemaking as a discourse practice that promotes conceptual understanding in science CLIL classrooms has not been explored yet. Overall, the literature review presented in this chapter highlighted many questions related to science learning in CLIL settings that have not been answered yet and that this study may contribute to explaining.

The theoretical framework adopted in this study is developed in the last part of the chapter. Overall, this study draws upon a sociocultural approach applied to science education with a focus on language and discursive practices employed for promoting participatory learning. In addition, the research study is informed by cognitive theories of bilingual education and is consistent with an orientation of language-as-resource. In regard to the orientation of language-as-resource, it was noted that no study in science education has explicitly adopted this orientation to language for investigating classroom discourse. Also, virtually nothing is known about how a CLIL science teacher's orientation towards language influences classroom discourse practices in general and translanguaging practices in particular. These are questions that this study may contribute to answering.

Finally, the construct of opportunities for learning science was analysed and defined for the purposes of this study. The literature review revealed that opportunities for learning science have only sporadically been adopted as a theoretical construct for investigating discourse practices in bilingual science classrooms.

Chapter 4 Methodology

4.1 Introduction

This study is concerned with science classrooms practices that promote opportunities for learning science when a CLIL approach is implemented. The previous two literature chapters (Chapter 2 and Chapter 3) have situated the research problem and the research questions in the pedagogical, social and cultural context which informs and conceptually frames this study. In particular, the literature review ended by identifying the conceptual lenses through which to look at the knowledge gap that was identified at the end of Chapter 2 (sections 2.11 and 2.12.3).

This chapter converts the conceptual framework into operational methodologies in order to appropriately address the research questions. Because this study explores the complex interconnection between science learning and teaching in CLIL settings through a situated/sociocultural lens to learning, a case study design and methods that yield rich data and comprise multiple perspectives were deemed most appropriate for this research. To achieve this, a mixed methods approach (suitable for collecting multiple participants' perspectives) was incorporated into a multiple-case study design (suitable for yielding rich data). The chapter mainly examines and justifies this design and methodology in relation to research questions, theoretical framework and philosophical paradigm.

4.2 Literature Gap and Research Purpose

The literature review conducted on both CLIL research and science education research areas has highlighted that most research so far conducted on CLIL hasn't specifically addressed the science education aspect, or has addressed it tangentially. Research actually focused on science education has mainly used quantitative methods for comparing learning achievements of CLIL and non-CLIL students (for example in Jäppinen, 2005; Piesche *et al.*, 2016) and produced inconclusive results which opened more questions than they answered. Qualitative research into CLIL with a focus on science education has tended to adopt a language learning orientation in design and analysis (e.g. in Evnitskaya and Morton, 2011; Moore and Dooly, 2010) and only few qualitative studies have looked at science learning in terms of developing either scientific reasoning (as in Bonnet, 2004) or the language register unique to science. As a result, very little is known about the effects of CLIL on science learning.

So far, this lack of evidence-based research concerning science instruction in CLIL settings has left educators without practical guidance and has caused some representatives of science teaching to develop an aversion to CLIL approaches (e.g. in Breidbach and Viebrock, 2012; Haagen-Schützenhöfer *et al.*, 2011). The present study aims to contribute to developing understanding of bilingual science education by shifting the prevalent perspective of CLIL research to that of science learning research *in* CLIL settings. In particular, the purpose of this study is to explore and understand opportunities for learning science when a CLIL approach is implemented in German and Italian secondary upper level science classrooms.

4.3 Research Questions

In formulating the research questions for this study, I was most concerned in focusing on how opportunities for learning science become visible in the CLIL classroom when both teachers and students participate in the science dialogue. I was also interested in including the perspectives of teachers and students in the investigation. These two foci represent the two specific aims of this research study, as represented in Figure 4.1. An overarching research question was formulated:

> How is science learning supported by classroom discourse when a CLIL approach is implemented in three case studies involving German and Italian upper secondary level science classrooms?

In addition to this main research question, four sub-research questions emerged:

1\. What interactional discourse practices promote opportunities for learning science when a CLIL approach is implemented at upper secondary level? (RQ1)

2\. What teaching discourse practices promote opportunities for learning science when a CLIL approach is adopted at upper secondary level? (RQ2)

2\. What are teachers' goals and epistemological beliefs about teaching science through a CLIL approach and how do they affect classroom practice? (RQ3)

3\. What are upper secondary level students' perceptions of learning science through a CLIL approach? (RQ4)

The first two questions (RQ1 and RQ2), in particular, might be considered as a subset of the overarching research question addressing how discourse practices facilitate opportunities for learning science, while the following two (RQ3 and

RQ4) are intended to capture the two different perspectives in this study, namely, the teacher participants (in terms of goals and epistemological beliefs) and the student participants (in terms of perceptions).

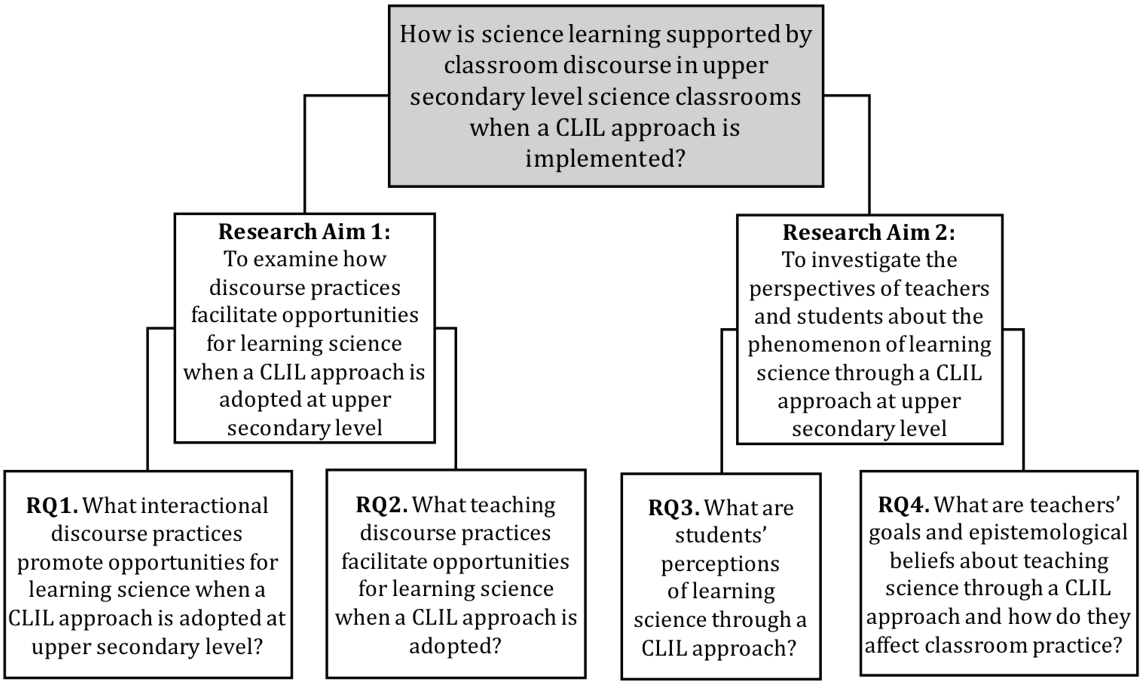

Figure 4.1 Summary of main research aims and questions.

Different methods for both collecting and analysing data have been implemented for answering the research questions. These are presented and discussed in this chapter. Table 4.1 provides a brief overview of these methods and of the dimensions and sub-dimensions they investigate in relation to the research questions.

Table 4.1 Relationship between research questions, investigated dimensions, sub-dimensions and employed tools or methods.

Research Question	Investigated dimensions	Sub-dimensions	Main investigative tools/methods
RQ1	Opportunities for learning science in *classroom interactions* (conceptual understanding of science and science language development)	- Accessibility to science content through interactions - Students' cognitive engagement and sensemaking - Students verbal production about science - Science language development	**Classroom observations + classroom audio-recordings** [interactions analysis of classroom discourse: QUAL. + QUANT.]
RQ2	Opportunities for learning science in *teaching discourse practices* (conceptual understanding, epistemologies of science and science language development)	- Accessibility to and development of science content, processes and values - Language use (e.g. translanguaging)	**Classroom observations + classroom audio-recordings** [thematic analysis of classroom discourse: QUALITATIVE]
RQ3	Teacher's goals and epistemological beliefs that affect science teaching thorough a CLIL approach	- Pedagogical goals - Professional identity and responsibilities - Epistemological beliefs - Language beliefs - Challenges and opportunities	**Teacher interviews** [thematic analysis on the transcripts: QUALITATIVE]
RQ4	Students' perceptions about science learning through CLIL	- The level of participation - Affordance of scaffolding - Translanguaging practices - Task difficulties - General attitudes towards the approach	**Student questionnaires** [QUANTITATIVE]

4.4 Influence of the Theoretical Framework on the Study

The theoretical framework, as described in section 3.7, frames research questions, design, components and analytical tools, as illustrated in Table 4.2. The theoretical framework of this study can be summarized as being centred on opportunities for learning science, which are conceptualized within a sociocultural dimension of learning (Greeno, 1998; Tobin, 2012; Vygotsky, 1978), when discursive practices are at work (Cazden, 2001; Halliday, 1993; Sfard, 2008) and the learners are using a foreign language (Cummins, 1979; 1980; 2000) that is considered as a resource like any other language they use (García, 2009; Planas and Civil, 2013; Ruíz, 1984).

Table 4.2 Research questions, main theoretical components and their influence on the study.

RQ	Theoretical Framework	Significant Conceptual Lens	Influence on Research Design	Influence on Analysis
RQ1	Vygotsky (1978) Rogoff (1998) Greeno (1998) Bruner (1978)	Students learn from participation in social interactions Learning is collaborative Learning is situated Learning occurs in the ZPD	Classroom observations + analysis of classroom discourse (interactions analysis)	- Accessibility to science content through interactions - Social participation and cognitive engagement - Social processes of sensemaking
	Cummins (1980) Schleppegrell (2004)	BICS, CALP and science academic language	Classroom observations + analysis of classroom discourse (interactions analysis)	- Student's verbal production about science - Students' development of science language
	Vygotsky (1986) Sfard (2008)	Cognitive development results from an internalization of language Thinking as Communicating	Classroom observations + analysis of classroom discourse (interactions analysis)	- Students' conceptual understanding and social interactions - Students' cognitive engagement and language use
	Gee (2008b)	Opportunities for learning science as socially mediated	Classroom observations + analysis of classroom discourse (interactions analysis)	- Conceptual understanding building - Science language development
	Bandura (1989)	Sociocognitive theory of learning	Classroom observations + analysis of classroom discourse (interactions analysis)	- Accessibility to science content through vicarious learning - Cognitive engagement and sensemaking as vicariously built - Science language vicariously developed
RQ2	Vygotsky (1978) Bruner (1978)	Learning occurs in the ZPD	Classroom observations + analysis of classroom discourse (thematic analysis)	- Discourse teaching practices and science content - Discourse teaching practices, science values and epistemologies
	Halliday (1993)	Language-based theory of Learning	Classroom observations + analysis of classroom discourse (thematic analysis)	- Language-focused discourse and conceptual understanding and science language development
	Ruíz, (1984)	Language-as-resource	Classroom observations + analysis of classroom discourse (thematic analysis)	- Translanguaging practices, conceptual understanding and science language development
	Stevens (1993)	Opportunities for learning science	Classroom observations + analysis of classroom discourse (thematic analysis)	- Conceptual understanding development - Building of science epistemologies - Science language development
RQ3	Vygotsky (1978)	Cognitive development, social interactions and ZPD	Teachers' interview	- Commitment to students' conceptual understanding through social participation
	Vygotsky (1986)	Cognitive development and language	Teachers' interview	- Commitment to science language development
	Ruíz, (1984) Tollefson (1999)	Language-as-resource Language beliefs affect practice	Teachers' interview	- Pedagogical goals, professional identity, and beliefs about language
	Cummins (1979)	Developmental Interdependence Hypothesis	Teachers' interview	- Beliefs about knowledge transfer between languages
RQ4	Greeno (1998)	Learning is situated	Student questionnaires	- Perceived level of participation and general attitude towards the CLIL approach
	Vygotsky (1978) Bruner (1978)	Learning occurs in the ZPD.	Student questionnaires	- Perceptions relating to scaffolding and task difficulty
	Ruíz, (1984)	Language-as-resource	Student questionnaires	- Perceptions relating to translanguaging practices
	Gee (2008b)	Opportunities for learning science	Student questionnaires	- Perceptions relating to participation, and scaffolding

4.5 Research Paradigm

This study adopts pragmatism as a research paradigm. Pragmatism as a philosophical school draws upon the work of Charles Sanders Peirce (1998), John Dewey (1920) and William James (1907), who were "all interested in examining practical consequences and empirical findings to help in understanding the import of philosophical positions and, importantly, to help in deciding which action to take next as one attempts to better understand real-world phenomena" (Johnson and Onwuegbuzie, 2004, p. 17). This study is interested in examining the "practical consequences" of classroom discourse practices through "empirical findings", in order "to help in" improving and orienting teaching practice to facilitate opportunities for learning science, through the understanding of "real-life phenomena", which are here case studies. These considerations make pragmatism the best paradigm for this study. In addition, pragmatism is viewed as the most useful philosophy to support the integration of qualitative and quantitative data in a study (Johnson and Onwuegbuzie, 2004). Indeed, this study investigates multiple sources of data by using mixed methods.

By endorsing a pragmatic logic, different methods for different inquiry components were chosen in order to examine different facets of the investigated phenomenon. In this study, the pragmatic philosophical approach permeates design (i.e. multiple-case study), methodology (mixed methods), the choice of data sources (use of a questionnaire, of semi-structured interviews, classroom observations and classroom talk transcriptions) and the presentation and interpretation of findings.

4.6 Research Design

4.6.1 Case Study Research

This study adopts a multiple-case study design, which is a particular adaptation of the most common case study design. Traditional case study design is first presented and then compared with multiple-case study design by highlighting the features of the latter that makes it a better design for this particular study.

Creswell (1998, p. 61) defines case study research as a methodology that involves the study of a phenomenon within a bounded system "through detailed, in-depth data collection involving multiple sources of information rich in context". Merriam (1988, p. 16) states that "case studies are particularistic, descriptive, and heuristic and rely heavily on inductive reasoning in handling multiple data sources". Yin (2009, p. 17) argues that case study design is appropriate for exploring a phenomenon "in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident". Even though researchers have interpreted the term *case study research* in many different ways, there are some commonly-agreed principles. Most definitions agree on the boundedness, the particularistic nature of the case, the context richness, the availability of multiple sources of information, and the in-depth nature of the investigation (Duff, 2008).

Case studies are widely used in social science research, across many disciplines (Creswell, 2007; Creswell, 2013) and are a common methodology in educational research (Miles, 2015). Case study research can be quantitative or qualitative in nature (Yin, 2009) or it can incorporate mixed methods (Kitchenham, 2010). In this research, a case study design provides both a suitable frame for an in-depth, detail-rich investigation and sufficient flexibility to employ multiple sources of data and mixed methods analyses. A case study design also fits the need for observing a complex social phenomenon (i.e. the classroom) in its real-life.

4.6.2 Multiple-Case Study Research

When multiple units of analysis are present in a study framed as case study, this qualifies as a *multiple-case study* (Stake, 1995). In this sense, several *instrumental* and *bounded* cases are selected to help better understand the complexities of the phenomenon (Mills *et al.*, 2010). *Instrumental* means here that the cases (e.g. schools, classrooms, people) provide insight into something else, i.e. a phenomenon of interest of which they constitute exemplars. In this study, the phenomenon that is examined is the opportunity for learning science in CLIL classrooms. Instrumental case studies are opposed to *intrinsic* case studies, which are undertaken because the case itself is of interest (Stake, 2000). *Bounded* means that there is a clear demarcation of what constitute the case studies. As compared to single-case studies, multiple-case designs are more powerful because the greater variation across the cases is likely to provide more extensive and compelling explanations of the phenomenon under scrutiny (Merriam, 1997).

In this study, the rationale for choosing a multiple-case study design lies in the hypothesis that three cases build together a more robust and instructive example of the phenomenon that is investigated. According to some authors multiple-case studies gain weight in terms of analytical power, external validity and generalizability (Campbell, 1979; Merriam, 1997). The aim of this study is to explore classroom practices in relation to opportunities for learning science. By expanding the number of units of analysis there is a greater chance of encountering more practices that generate opportunities for learning science and to get a deeper insight into them. For instance, this is the reason that guided the decision to add another unit of analysis *after* the first two had been preliminarily analysed. As the main aim for choosing multiple-case studies was to seek an accurate understanding of the phenomenon, a cross-case analysis was not sought *per se*, meaning that the researcher was not interested in comparing cases (cf. Stake, 2013). However, some of the most interesting findings of this study emerged as a result from comparisons across cases. Indeed, Stake (2005) claims that the examination of similarities and differences across cases facilitates the identification of cause-and-effect relationships.

In terms of demarcation of the units of analysis—as recommended by Merriam (1997) and Stake (2008)—the case of this study, or the units of analysis, are three specific educational contexts. All of them have in common the following major features: the subject matter is biology, the pedagogical approach is CLIL, the school level is upper secondary, students are all aged between 15 and 17 years. Each case is represented by a teacher and his or her students. Each teacher operates in a different educational environment: a different school, from a different city and, in one case, also from a different country. Also, what the participants accomplish together is part of the cases. The temporal boundaries of the units of analysis are the time frames of the data collection, which were approximately ten consecutive days for each unit. The profiles of the case studies, in terms of settings and participants are summarized in Table 4.3 and further described in section 4.8.2. In terms of analysis, data from different case studies were analysed both across the whole data set and across cases.

Table 4.3 Case studies profiles.

	School	Teacher	Students
Case 1 (CS1)	Urban mixed-gender *Gymansium* (in Hamburg, Germany). Emphasis on the teaching of languages and a bilingual education. It offers an International Baccalaureate (IB) programme in the last two upper years on a voluntary basis.	**Alexandra** Native German-speaker. 6 years CLIL teaching experience (12 years teaching experience overseas before that)	3 classes: one in grade 11 and two in grade 10 (A and B). Students are aged 15 to 17
Case 2 (CS2)	Urban mixed-gender *Gymansium* (in Berlin, Germany). It offers a bilingual education to some of its classes.	**Emma** Native German speaker. 2 years CLIL teaching experience (15 years overall teaching experience). She teaches both Biology and English (as a Foreign Language)	3 classes: one in grade 11 and two in grade 10 (A and B). Students are aged 15 to 17
Case 3 (CS3)	Urban mixed-gender *Liceo* (in Trento, Italy). Emphasis on the teaching of modern languages (*Liceo Linguistico*). It offers a bilingual education in some subjects to all students.	**James** Native American English-speaker. 6 years CLIL teaching experience	4 classes: in grade 11 (A, B, C, D) Students are aged 16 to 17

4.7 Research Methodology: Mixed Methods

Within a multiple-case study design a mixed methods approach to collect and analyse data was implemented. Johnson, Onwuegbuzie and Turner (2007, p. 17) effectively describe mixed methods research as “the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches or concepts in a single study”. However, there is a growing consensus that mixed methods research involves more than just the joint use of qualitative and quantitative data. For example, Tashakkori and Creswell (2007, p. 4) argue that in mixed methods research “the investigator collects and analyses data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods”.

In this study, the adoption of a mixed methods approach expanded the breath and scope of enquiry and allowed the researcher to explore the complex and multifaceted phenomenon of learning science in bilingual settings from different perspectives. In particular, students’ perspectives were investigated through a questionnaire. The teachers contributed with their individual perspective through a semi-structured interview. Classrooms were observed and discourse audio-recorded. Therefore, mixing methods was consistent with the purpose of the study.

In particular, this study adopts a qualitatively-driven approach to mixed methods, meaning that the qualitative component represents the dominant approach (cf. Johnson, Onwuegbuzie, de Waal, Stefurak and Hildebrand, 2017; Johnson *et al.*, 2007). The mixed methods design adopted in this study is an adaptation to the model that Creswell and Clark (2011) define as a *convergent parallel mixed methods design model,* meaning that, within each case study, both qualitative and quantitative data were collected simultaneously. With respects to the integration phase, findings from different sources were integrated in the final interpretation phase after having been separately analysed. An overview of the workflow of this study is represented in Figure 4.2, which also relates different research components to specific research questions.

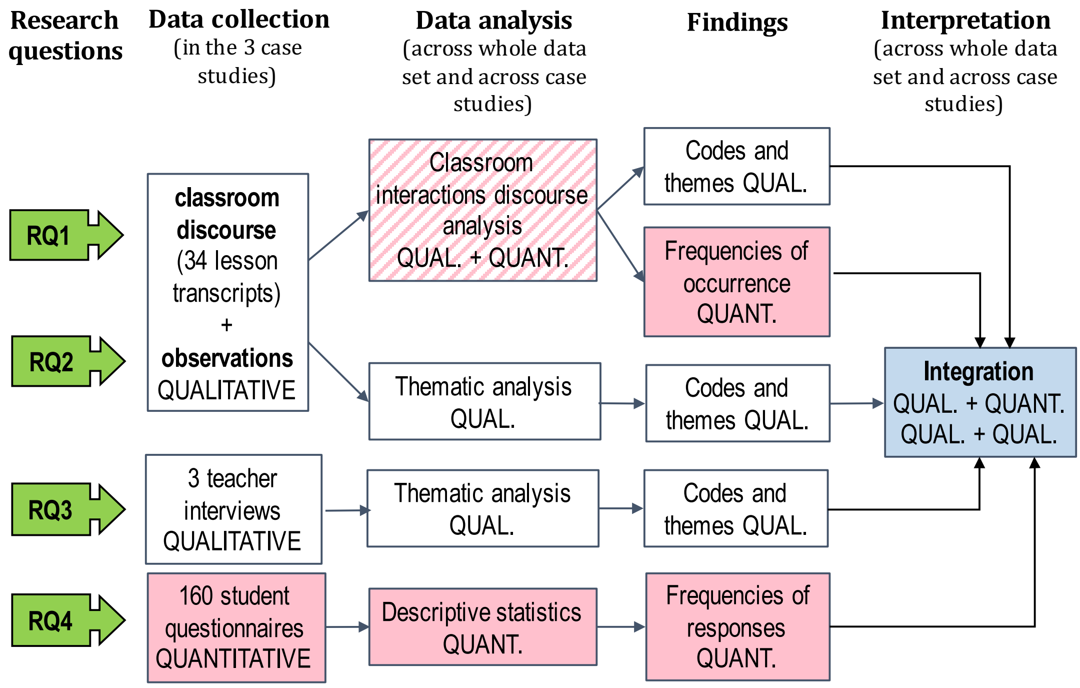

Figure 4.2 The workflow of this study adapted from Creswell and Clark (2011). Qualitative elements of the research are white, quantitative are pink, integration between data is blue. The pink and white stripes pattern indicates when mixed methods were used on the same data source.

4.8 Research Samples

Three case studies were selected and examined as the object of this study. An overview of the cases' profiles in terms of contexts and participants is provided in Table 4.3. Each case study is settled in a different secondary school: two

Gymnasien in Germany (Hamburg, case study 1, or CS1, and Berlin, case study 2, or CS2) and one *Liceo* in Northern Italy (Trento, case study 3, or CS3). Each case study is populated by a biology teacher (n=3) and their senior classes (students aged 15 to 17). A total of ten class groups (n=175) participated to this study.

For sampling, a purposive—or non-probability—sampling strategy was chosen. Purposive sampling is defined by Patton (2002, p. 46) as a technique for identifying and selecting information-rich cases in order to make the most effective use of limited resources. Purposive sampling designs are commonly used in case study research (Fraenkel, Wallen and Hyun, 2012). In purposive sampling, the researcher uses some criteria or purpose instead of the principle of minimum sampling error (Kemper, Stringfield and Teddlie, 2003). As Patton (2002) explains, the power and logic of probability sampling is generalization, whereas the power and logic of purposeful sampling derives from its potential of achieving in-depth insight. Accordingly, purposive sampling was chosen because the goal of this study was not to generalize results to a population but to deeply understand a phenomenon with the limited resources of a PhD study. The strategy for selecting the samples was criterion-based, meaning that the logic of selecting was to only include case studies that met some predetermined criteria (Patton, 2002, p. 238), specifically: (a) the accessibility of samples, (b) the level of insight the samples were expected to bring to the study, and (c) a certain level of homogeneity between the cases. These aspects are examined in the next sections.

4.8.1 School and Teacher Recruitment

The abovementioned criteria for selecting samples also explain why the three cases of this study are settled in Germany and in Italy and why they are geographically far from each other. In particular, accessibility was facilitated by the fact that the researcher speaks the language of the countries where data were collected, i.e. German and Italian. Therefore, the schools were sought in countries where these two languages are spoken. It may seem a trivial aspect, but classroom research means for a researcher to seek and negotiate his or her access to a school by making contact with many people, and not all them speak a *lingua franca*, i.e. English. In addition, a considerable paperwork is involved, and typically this has to be in the language of the hosting country.

In order to maximize the level of insight that samples could bring to the study—i.e. the second criterion for choosing samples—the personnel of local education departments and local university staff with an expert knowledge about the network of schools offering CLIL education in these locations, were asked to recommend schools. For the purpose of this study, only experienced teachers in science teaching and CLIL pedagogies were recruited. This choice was justified by the fact that this study is concerned with effective teaching practices. Berliner (1986), Tobin and Fraser (1989) argue that the investigation of expert teachers can provide extremely useful material from which less experienced teachers and educators are likely to benefit.

Finally, a certain homogeneity between cases was necessary for sensibly allowing across-case comparisons. This was achieved by selecting samples where all student participants attended an upper secondary biology course. All student participants were also taught biology through the same pedagogical approach, i.e. a “strong” CLIL approach (meaning immersion-like, as explained in section 2.8), in English, throughout the whole school year. Moreover, all the students had been learning biology in English for at least one school year prior to participating in this study. Finally, English competences of the students ranged from good to very good.

In order to combine high levels of insight with accessibility of samples and the outlined desired characteristics, case studies ended up by being in geographically detached locations. In other words, it was not possible to conveniently find more than one case study that met the required criteria in the same location. As a result, although being rather homogeneous, the three case studies also display apparent differences, such as the diversity of geography, schools’ systems, (first) languages and cultures. Another source of variability is represented by the teachers (i.e. teaching styles, personal experiences, beliefs, culture and values). This combination of homogeneity and heterogeneity was considered as an interesting mix for studying the phenomenon of science learning in CLIL environments. After all, CLIL is a European product and these case studies represent pieces of Europe. Overall, the similarities were expected to outweigh the differences and the case studies were expected to produce relatively similar outcomes. In multiple-case studies research this condition is referred to as *literal replication*, which is relevant for enhancing the general validity of the study Yin (2009).

In this study, the three science teachers—each of them representative for one of the case studies—teach in three different schools, two in Germany (Hamburg and Berlin) and one in Italy (Trento). To facilitate comparisons between case studies, the examined Italian classes were compared to the German school system on the basis of the age of the students. For this study, only grade 10 and grade 11 classes (*Jahrgangsstufen* 10 and 11) as referred to in the German school system were investigated. Grade 10 classes are populated with students aged 15 to 16, and grade 11 classes are populated with students aged 16 to 17. Grade 11 precedes the final year (grade 12), which ends with the final state exam (*Abitur* in Germany, *Esame di Stato* in Italy). Table 4.3 provides a profile of the three case studies, in terms of school typology and participants. A more detailed profile of each case study follows in the next section. There were no students with special educational needs. The schools were all mixed-gender with a proportion of girls always higher or slightly higher than that of boys. This could be explained by the schools' emphasis on modern foreign languages, which traditionally attract more girls than boys (see, for instance, Davies, 2004). However, the gender factor is here not considered as it goes beyond the scope of the study. Indeed, the focus of this study is on classroom discourse and gender differences in participation to classroom discourse and/or science learning were neither sought nor empirically observed.

4.8.2 Case Studies Profiles (Settings and Participants)

Case study 1 — CS1: This case study is settled in a mixed-gender state funded secondary school (Gymnasium) in urban Hamburg, Germany. The participants are the students of two Grade 10 and one Grade 11 classes (students aged 15 to 17 years) and their female science teacher. The classes are mixed-gender, with an average gender ratio of 17 girls to 5 boys. The students who participate in this study have been learning bilingual biology since Grade 9, two or three hours per week. Their level of English is either good or excellent. The school they attend emphasizes the learning of languages through both English as Foreign Language instruction (ELF) and CLIL. All the students are provided with six hours per week of ELF instruction in Grades 5 and 6 (students aged 10 to 13 years); and from Grade 7 they receive CLIL-instruction (*bilingualer Fachunterricht*) in history combined with 4 hours of ELF per week. Progressively, other bilingual subjects are added each year and are maintained until the end of Grade 11: geography starts in Grade 8 and biology in Grade 9. The school's policy on CLIL instruction is for the students to achieve a near-native fluency in English and to also provide the students with the necessary disciplinary German vocabulary. In Grade 12—the last year of instruction—the classroom language is German in all the subjects because the final exam (*Abitur*) is in German.

The science teacher of this case study, Alexandra, has been teaching biology in a bilingual programme in Germany for 6 years. Prior to this, she qualified as a science teacher in the UK where she taught to native English-speakers for a while before moving to Asia, where she taught biology in Singapore and Vietnam to non-native speakers. When moving back to Germany her greatest challenge was to actually teach biology in German, her mother tongue. Only later, did she begun to teach bilingual biology to German students. Her teaching expertise in bilingual education basically relies on her experiences.

Case study 2 – CS2: This case study is settled in a mixed-gender state funded secondary school (Gymnasium) in urban Berlin, Germany. The school emphasises the learning of foreign languages and adopts CLIL as an approach (*bilingualer Zug*) for teaching various non-linguistic subjects. Compared to the school of CS1, this school has a greater portion of students whose mother tongue is not German. The participants of this case study were the students of two Grade 10 and one Grade 11 classes (students aged 15 to 17 years) and their female science teacher. The classes are mixed-gender, with an average gender ratio of 13 girls to 10 boys. The school they attend has no particular designation. However, it offers a bilingual stream (bilingualer Profilierung) from Grade 7 with a CLIL approach. All the students have been learning English as first FL from grade 5. The students who participated in this study have been enrolled in the bilingual stream and have been learning biology in English (CLIL) since Grade 7, three hours per week. At grade 7, to first enrol in bilingual biology, students are required to have high marks both in biology and English prior to year 7. In addition, parents who wish to enrol their children to this stream are advised to meet the teacher in a personal consultation meeting. A one-year probation time at grade 7 is requested before allowing them to continue to learn bilingual biology. Also in this school, in Grade 12 the language of instruction for any non-linguistic subject is German.

The teacher of this case study, Emma, teaches both Biology and English (as a Foreign Language), at the same level. German universities allow students to combine two subjects as a major for completing their bachelor’s degree. As a result, in Germany, it is relatively common for teachers at secondary level to teach two different subjects. Usually, the two subjects are closely related, but exceptions may be possible and Emma is one of those. She is qualified for teaching both English and Biology, which she has been doing for more than 15 years at different secondary schools in Berlin, but only since 2014, has she been teaching biology in English. Besides teaching biology in English, Emma also teaches English as a Foreign Language at her school. She has never been specifically trained to teach science in English, her expertise is mainly based on personal experience. At the time of the visit to her school, Emma was the only teacher teaching biology in English.

Case study 3 – CS3: This case study is settled in a mixed-gender state funded secondary school (Liceo Linguistico) in urban Trento, North Italy. The average gender ratio of the school is 69 percent female to 31 percent male. This ratio was reflected in the observed classrooms.

The participants of this case study were the students of four Grade 11 classes, and their male science teacher. A Grade 11 class corresponds to a fourth class of the

Italian secondary upper school. The school where this case study is located is a Liceo Linguistico, meaning a secondary school that is focused on the teaching of foreign languages. Three foreign languages are taught from Grade 8 to Grade 12, English and German being two of these. The school offers one subject taught through a CLIL approach from Grade 8. In Grades 8 and 9, the CLIL approach is implemented only partially on the non-linguistic subject, either using English or German as the target language. In Grades 10, 11 and 12 two non-linguistic disciplines are integrally taught through a CLIL approach. The participants of this case study have all been taught biology in English since Grade 10.

The teacher of this case study, James, is a native American English speaker. He graduated in biology in the US. After moving to Italy, he has been teaching science in English at secondary level for 6 years. Prior to this he taught in a bilingual school at primary level.

4.9 Data Collection

Data were collected in each case study location over a period of two weeks, between October 2016 and March 2017. The pilot study was conducted in May 2016 (as further explained in section 4.10). An overview of the fieldwork components of this study is provided in Table 4.4.

Table 4.4 Overview of fieldwork components.

Location of fieldwork:	Three different schools: Hamburg (Germany), Berlin (Germany), and Trento (Italy)
Number of classroom observations:	34 (+ 6 in the pilot study)
Number of audio-recorded hours:	34
Number of interviews with teachers:	3
Duration of fieldwork:	6 months: from October 2016 to March 2017 (+ one week of pilot study in May 2016)
Number of participants:	3 teachers 175 students (aged from 15 to 17 years)
Number of questionnaires collected:	160 questionnaire

The data collection was guided by the research questions. For each research question, specific data collection strategies and tools have been designed and implemented as summarized in

Table **4.5**. In particular, these strategies and tools involved:

- *direct observations of lessons with relative field notes:* a total of 34 class periods of 50 minutes' duration each on different topics of biology were observed and field notes taken using a semi-structured observation schedule (15 class periods in CS1, 8 class periods in CS2 and 11 class periods in CS3);

- *the audio-recording of the classroom talk*: the classroom talk of 34 class periods was reduced to relevant parts only (approximately 23 hours of conversation) and transcribed verbatim, producing a corpus of approximately 120,000 words.

- *a questionnaire to the students* on their perceptions (n = 160 questionnaires collected);

- *an individual follow-up interview with each science teacher*.

Table 4.5 Data collection and analysis method in relation to research questions.

Research questions	Data collection methods	Data collected	Analysis methods
RQ1 – Re: interactions that promote opportunities for learning science	Classroom observations Classroom audio-recording	field notes and transcripts (34 class periods)	Classroom observations + Classroom interactions discourse analysis
RQ2 – Re: teaching discourse practices that promote opportunities for learning science	Classroom observations Classroom audio-recording	field notes and transcripts (34 class periods)	Classroom observations + Thematic analysis
RQ3 – Re: Teachers' goals and epistemological beliefs	Teacher follow-up interviews (audio-recording)	3 interviews	Thematic analysis
RQ4 – Re: Students' perceptions	Student questionnaires	160 filled-in questionnaires	Descriptive statistics

The questionnaire and the tool for observing classroom activities were both designed, piloted and redesigned. For each case a similar time boundary for data collection was used and the relevant procedure was replicated.

4.9.1 Classroom Observations

As Cohen, Manion and Morrison (2011) maintain, observations offer "the opportunity to gather *live* data from naturally occurring social situations." In this sense, data collected through observations are truly first-hand accounts, which makes them potentially more valid and authentic than any other data gathered through mediated methods. Observations provide what Robson (2002, p. 310) calls a "reality check', because they capture what people actually do, which may differ from what they say they do (Gillman, 2003).

The observations in this study focused on classroom events potentially useful for answering the research questions. Concurrently, participants were also audio recorded as they engaged in classroom discourse. Observations were conducted by the researcher and involved the recording of detailed field notes in the form of *observation schedules* (Figure 4.3). These were systematically filled with data regarding people (students and teacher), settings, topics, activities. In particular, the recorded observations included information about non-verbal behaviours and about everything relevant to the research questions that could not be captured on an audio track (cf. Mac Mahon, 2014), such as information on gestures, tools and activities (i.e. small group activities, use of media, presentations, models, visuals, whiteboard use). During the early steps of the analysis, these data were integrated with classroom discourse transcriptions.

The observations collected throughout this study might be described as *semi-structured* because they respected a set agenda of intents and issues to look at, but there wasn't a predetermined list of categories to consider (Cohen *et al.*, 2011). This allowed the researcher to maintain the same focus throughout the whole set of observations (34 class periods). On the other hand, the recording schedule was sufficiently loose to allow the research to capture the variability and unpredictability of human interactions.

To preserve the naturalistic approach to data collection, the researcher tried not to influence the observed environment and acted as a *non-participant* (Cooper and Schindler, 2001) or *complete observer* (Gold, 1958). It has been argued that a researcher could never study a world without being part of it and somehow influencing it (Adler and Adler, 1994). Nevertheless, the researcher behaved in a manner to detach herself from the participants and to not be noticed. For instance, an inconspicuous observation point in the classroom was agreed with the teacher before the lesson. While being unobtrusive was relatively difficult at the beginning of a set of observations in a class, it became relatively easy as the participants got accustomed to her presence. What students and teachers were engaged with during observations was uniquely a choice of the teacher and was not influenced by the researcher presence. However, it is still possible that teachers decided to organize their lessons in such a way as to minimize non-verbal activities, such as class tests, when the researcher was present. As a matter of fact, the researcher—prior to visiting the schools—informed the teachers that the focus of observations was on classroom talk.

In relation to the whole research design, observations were used as a supplementary technique to complement audio-recordings, to better examine opportunities for learning science in classroom discourse and to better interpret both teacher interviews and student questionnaires. As Gillman (2003) highlights the *convergence* of different kinds of data, gathered in different ways but bearing on the same point, is at the heart of the case study method.

<table>
<tr><td colspan="4">Date: Location/case study: No Students: ____
Class: Teacher: (# Male st.:____ # Female st.: ____)</td></tr>
<tr><td>Phase Units:
(goal/topic)</td><td>Time:</td><td>Sequence Unit:
(sub topic/activity)</td><td>- What teacher and students do.
- Non-verbal data (gestures, movements...)
- Use of hands-on, media, textbooks, models, whiteboard.
- Researcher's notes.</td></tr>
<tr><td>✍………………</td><td>✍………</td><td>✍…………………</td><td>✍…………………………………</td></tr>
</table>

Figure 4.3 Observation schedule used for collecting data during observations.

4.9.2 Audio-Recordings of Classroom Discourse

While observing 34 periods of biology (50 minutes' duration each), verbal data were audio-recorded and subsequently transcribed verbatim. The audio-recording resulted in approximately 23 hours of transcribed conversation, as non-relevant parts of the classes were not transcribed (e.g. media presentations, reading activities, most of the team-work activities, and preliminary activities such as class announcements were not included). As a last step, these transcripts were integrated/complemented with the researcher's observations (described in the previous section).

During whole-class talk, one audio-recorder was positioned in the back of the classroom. The recorder captured all of the teacher talk and many of the students' comments during whole-class discussions. The parts of the audio-recordings that were relevant to the study were then transcribed and analysed. Coupled with the observations, this source of data was meant to help answer the first two research questions (RQ1 and RQ2), addressing classroom discourse practices that promote opportunities for learning science.

The collection of this source of information was chosen for its relevance in the building of science knowledge in a situated sociocultural perspective of learning (Mercer, 2004). The importance of spoken language as a means of expressing ideas, building thoughts and cognition and communicating was explained in Chapter 3, sections 3.4 and 3.5.

In this study, the use of classroom discourse as investigative tool is conceptually framed by the seminal work of Jay Lemke (1990) and the sociocultural approach to discourse theorized by Gee (1989, 2004), Cazden (2001), and with the important contribution of Mercer (2004, 2010). This literature sources influenced how classroom discourse was both collected (i.e. naturalistic, non-interventional approach) and interrogated. The latter aspect is discussed in the analysis sections (from section 4.13 to 4.14.3) of this chapter.

4.9.3 Teacher interview

At the end of each data collection campaign a semi-structured interview with the teacher was held. This method to collect data was chosen to specifically answer research question RQ3, addressing teachers' goals and epistemological beliefs. The interest into exploring teachers' epistemological beliefs is based on the theoretical assumption that science teachers' beliefs about the nature of knowledge and about language affect and effect teaching practices (Hashweh, 1996; Tollefson, 1999).

In terms of theoretical justification for using research interviews, it often occurs that they enhance the validity of research findings by serving as an auxiliary method in conjunction with other methods of contemporary social science research, as highlighted by Merriam (2002, p. 12) and Kvale (2007, p. 46). In this study, interviews complemented other sources of data. Through interviews, teachers shared their teaching goals, pedagogical choices, experiences and epistemological beliefs about the implementation of a CLIL approach (cf. Luft and Roehrig, 2007). Therefore, each and every interview offered an invaluable perspective for better understanding the phenomenon under investigation.

The interview design was roughly in the middle of a continuum between being structured and being flexible. A flexible schedule of questions asked by the researcher functioned as trigger that encouraged the participant to talk and allowed the researcher to steer the interview to obtain the data relevant for the study. Formally, these are known as *semi-structured* interviews (Barriball and While, 1994). While the structured feature allowed the researcher to compare data from different interviews, the relatively flexible schedule enabled the researcher to better explore attitudes, values, beliefs and motives, as also noted by Richardson, Dohrenwend and Klein (1965) and Smith (1992). The implemented semi-structured interview schedule consists of three parts: the first one is dedicated to collect background information, the second is focused on teacher's epistemological beliefs and goals, the third part closes the interview. The interview schedule (provided in Appendix A) consisted of a relatively small number of open-ended questions. An extensive review of the literature informed the construction of the questions by delineating areas of interest and relevance that should be covered by the interview. Not all the questions incorporated in the schedule were actually used during each interview, but they represented the general backbone for the interviews. From this list of questions the most appropriate ones were picked out according to the context. The interviews started with factual questions on the teacher's background and moved on to more personal opinions. Interviewees were also encouraged to elaborate with experiences or examples.

Each interview lasted approximately 30 minutes even though there were no fixed time limits. The interviews were all audio-recorded with the written agreement of the teacher.

Overall, the major challenge experienced by the researcher was to find the right balance between maintaining control of the interview and "allowing the interviewee the space to redefine the topic under investigation and thus to generate novel insights for the researcher" (Willig, 2013, p. 24). A carefully constructed interview schedule helped the interviewer not to lose sight of the original research question. Another challenge was the language of the interview. Both interviewer and, in two out of three cases, the interviewees were not native English-speakers (Marshall and While, 1994). Finally, the audio-recorded interviews were transcribed verbatim. Interviewees were reminded that they would receive a copy of the interview transcript and that they could amend or comment on it.

4.9.4 Student Questionnaire

Research question RQ4 of this study is concerned with students' perceptions about science lessons in relation to the adoption of a CLIL approach. Participants' perceptions are explored in the present study because they affect both emotions and behaviours which are important factors that shape learning environments (Tacca, 2011). Therefore, students' perceptions play an important role in shaping cognitive processes (Goldstone and Barsalou, 1998). Moreover, the investigation of students' perceptions complements other sources of data (classroom discourse, classroom observations, teacher interview). As Fraser (2001) noted, students are in a good position to give a consistent picture of the long-standing features of the learning context, even if teachers are inconsistent in their day-to-day behaviour.

Students' perceptions were collected using a questionnaire. This research instrument offered the practical advantage of being easily understood and authorized by school authorities and parents. As the questionnaires were anonymous, ethical issues were also minimal. Apart from theses practical reasons, a questionnaire was also chosen because its quantitative analysis does not rely on the researcher's interpretation as opposed to the other data sources of this study (i.e. observations, classroom discourse and interviews).

In terms of instrument design, the questionnaire was assembled to specifically serve the needs of answering the research question RQ4, addressing the students' perceptions of learning science through a CLIL approach. The questionnaire was designed to exclusively collect quantitative data (i.e. only closed-ended questions were included). This choice was considered the most prudent because the questionnaire was administered in English to English language learners. The questionnaire administered to the students is displayed in Appendix B.

The first and main section of the questionnaire consists of 6 scales and 36 items. The six scales are *Involvement*, *Investigation*, *Personal Relevance*, *Uncertainty of Science, Anxiety and Enjoyment of the CLIL Science Lessons and Understanding* and *Communicating Science through a Second Language.* All the items are measured on a 5-point Likert frequency scale. The frequency-response alternatives for each item are Almost Never, Seldom, Sometimes, Often and Very Often. In the second section, a separate scale—*How difficult?*—investigates the perceived difficulties that students may encounter in using a foreign language to study science. The difficulty-response alternatives for each item of this scale are Very difficult, Difficult, Neutral, Easy, Very Easy. As a result, a 50-item questionnaire was designed. The 50 items are placed in recurrent order, meaning that the first item of the first scale is followed by the first item of the second scale and so on. A list of the scales and the items is displayed in Appendix C. An extensive review of the literature informed the construction of the questionnaire.

Because the target of the questionnaire are students whose first language is not English, comprehensibility is maximized by using a clear wording without jargon or abbreviation (e.g., CLIL acronym was never used), avoiding double negatives, and omitting negative items and those items considered `conceptually complex' (Aldridge and Fraser, 2000). The comprehensibility of the questionnaire was also enhanced by first piloting the questionnaire, as explained in section 4.10.

The final questionnaire was administered to 160 students, which is less than the total number of student participants (175). The difference is due to the fact that one class was engaged in a school activity the day the questionnaire was scheduled. Unfortunately, it was not possible to reschedule the questionnaire.

Therefore, despite all the students agreeing to contribute to the questionnaire, not all of them actually filled it in.

In two locations (Trento and Hamburg), the questionnaire was always compiled in the presence of the researcher. This modality of administration was helpful in that it enabled any queries to be addressed immediately. In Berlin, the questionnaire was administered by the class teacher, who had been first informed by the researcher about any potential problem. According to the feedback of the teacher, no issues occurred during the completion. In general, the questionnaire was well received by the students and the totality of questions were answered.

4.10 Pilot Study

A pilot study to test the research strategies and tools for collecting data was conducted in May 2016 during six lessons at the CS3 location. These class periods were observed over one week. In particular, the questionnaire to the students and the recording schedule for collecting structured observations and the audio-recording modalities were exposed to the rigours of the field under conditions similar to those of the main study. The data collected during the pilot study were not included in the analysis of the major study, as recommended by Lackey and Wingate (1998). Whereas the appropriateness of the recording schedule for classroom observations was confirmed during the pilot study, the final pilot draft of the questionnaire indicated that some changes were needed in order to ensure its validity as instrument tool.

The aim of testing the questionnaire was to ensure that the questions were being asked accurately and that the respondents could answer the questions (Grimm, 2011). In particular, the pre-testing was conducted to correct any ambiguity and ensure the clarity of both the wording of single items and the layout of the whole tool. The questionnaire was pilot-tested in a class of 14 students who were involved in the research solely for testing the questionnaire. Their English competence and experience with a CLIL approach in learning science replicated the characteristics of the respondents of the final study. The participants who tested the questionnaire were aware of the task they were assigned and the reasons behind it. This sample class was from the Italian school where four other classes took part in the overall study. During the administration of the questionnaire students were asked not to *think out loud* but to wait for the subsequent whole-class debriefing session. Students were discreetly observed and the average completion time was measured.

It took an average time of 15 minutes to fill out all the parts of the questionnaire and no items were left unanswered. After the administration of the questionnaire, the researcher collected the respondents' reactions to the questionnaire through an informal debriefing session. The teacher was also asked to collaborate with his own comments. More specifically, the researcher wanted to investigate if the respondents clearly understood what was being asked. All the questions raised by the students and the observations provided by the teacher were recorded and used to improve the final version of the questionnaire.

The participants only highlighted two linguistic problems: (1) some of them didn't know the meaning of *carry out*. This phrasal verb was replaced in the final version of the questionnaire with *perform*, which is more elaborate than the phrasal verb, but it is nevertheless a cognate that students understand better; (2) the noun *lab*, which was then replaced with *experiment*, for the same reason mentioned above. In addition, the transition from the scales that required an *Always-Never* answer —first section —to the final scale that was answered with *Difficult-Easy* —second section—was noted to cause some bafflements. This issue was handled by designing a graphic that helped to make the transition clearer. Some of the questions the students asked while testing the questionnaire revealed that some participants probably didn't read the instructions or read them superficially. The solution adopted to solve this problem, was to read or sum up orally the main points before administering the questionnaire.

The fact that the questionnaire only includes closed-ended questions was positively received by the students. Some of them were worried about having to write in English and expressed their relief when they found that all the questions were closed-ended.

4.11 Data Analysis

The presentation of methods implemented for interrogating data is organized around different types of data sources. Data of different nature (qualitative and quantitative) were analysed using different tools, chosen for their suitability to answer the research questions. Qualitative, quantitative and mixed methods approaches to analysis were implemented. Figure 4.2 provides an overview of the workflow of data throughout the research process and their relation to the research questions.

Data collected from the audio-recordings of the classroom talk were analysed both qualitatively (thematic analysis) and by using a mixed methods approach (interactions analysis on classroom discourse). Data collected from the teacher interviews were analysed qualitatively. Data collected through the student questionnaires were analysed quantitatively. In the final interpretive phase of the research process, findings extracted from different research components were integrated to better answer the research questions.

4.12 Data Analysis: Audio-Recordings

Audio-recordings were played back and transcribed verbatim by the researcher. A corpus of approximately 120,000 words resulted from the transcription process. This corpus covered 34 lesson periods of 50 minutes each. These were reduced to 23 hours of conversation, as media presentations and other non-relevant parts of the classes were not transcribed.

Transcriptions are labour intensive (Braun and Clarke, 2006; Lapadat and Lindsay, 1999), but rewarding, as the time spent on them informed the early stages of analysis and allowed the researcher to develop a deeper understanding of the data. The close attention needed to transcribe data facilitated the development of interpretative skills and the tuning into the transcribed data. However, transcripts are not raw data. Edwards (2001, p. 321) highlights that transcripts represent the first level of encoding of verbal data and as such, the first level of analysis, "a distillation of the fleeting events of an interaction, frozen in time, freed from extraneous detail." Transcripts are biased, reductive and reflect what the researcher chooses to preserve from the interaction and how to represent it (Ochs, 1979). As Lemke (2011 p. 1472) points out, the process of transcription "creates a new text whose relations to the original data are problematic" as transcripts are affected by researcher's choices, employed conventions, adopted theoretical framework and research questions (cf. Mishler, 1991).

For the purposes of this study, only dialogues related to science learning or teaching were transcribed. Other parts of the classroom talk—such as announcements regarding class projects or special events—were not transcribed and indicated in the original transcripts documents as *omitted*. Transcripts were integrated with supplementary information coming from direct classroom observation where the audio dimension alone wasn't enough to capture what was happening in the classroom in terms of science learning.

Transcripts were produced verbatim following the two criteria proposed by Edwards and Lampert (1993). These are: (1) authenticity, that is the transcript preserves the original information in a way which is true to the nature of the interaction itself; and (2) practicality, meaning that the transcripts conventions should be practical with respect to the way in which the data are to be managed and analysed. In this study, manageable transcripts meant that they had to be easy to write and easy to read. With respect to the level of exactness, the criterion proposed by Strauss (1987) was adopted. This maintains that transcripts should retain only the information that is needed to answer the research questions. Because the researcher was mainly interested in the verbal utterances, non-linguistic features of speech were usually not transcribed. Exceptions to this rule were represented by evident hesitations, laughs, incomplete sentences, false starts and repetition of words, as they were considered relevant for answering the research questions.

The basic procedure for producing transcripts was to go through the audio-recordings while producing a rough draft of the transcript by using Express Scribe NCH software. Then the researcher would go through this draft over and over again, filling in the gaps and making corrections. The major difficulties were in (a) catching utterances that were spoken relatively softly by the students, often spoken simultaneously with other utterances and with the speaker's head turned away from the microphone and (b) transcribing utterances that were spoken in more than one language or switching from one language to another.

In the presentation of findings of this thesis (Chapter 5 and Chapter 6), many extracts from the original transcripts are reported to support both presentation and discussion of results. The sources of quoted classroom transcripts are indicated with a code as in Figure 4.4.

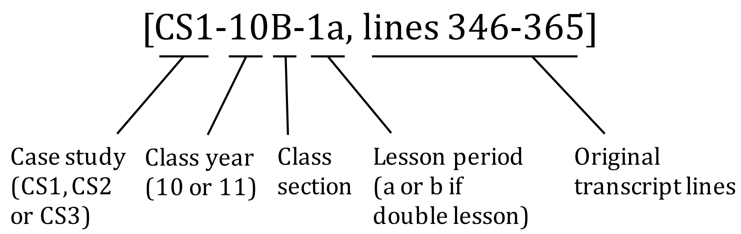

Figure 4.4 Illustrated example of a code indicating the source of a transcript.

In the original transcripts, all lines are numbered. The numeration of lines is avoided in the presentation of findings for readability purposes. However, sometimes lines numbers are necessary. In these cases, line numbers are reported and refer to the lines in the original transcripts. Table 4.6 provides the conventions employed for transcribing the classroom dialogues.

Utterances in L1 were transcribed and contextually translated to English to assist the reader. The translations are provided to assist the reader and are not intended to be literal but rather to provide the colloquial intent (as in Tuyay *et al.*, 1995).

Table 4.6 Conventions employed for the transcripts.

(3.0)	Measured pause, with seconds in brackets.
[ ]	Non-verbal action, or transcriber's comment, e.g. [inaudible]
...	An ellipsis (three dots) is used to indicate a short pause in speech, a trailing off, or a stammering hesitation too short to be measured in seconds but too long to be represented by a comma.
[...]	An ellipsis within square brackets indicates an omission from the original transcript.
[*sic*]	Some text enclosed in square brackets indicates a comment of the transcriber. *Sic*, in particular, indicates that the transcriber wants to make it clear that a mistake (immediately before [*sic*]) is contained in the original speech.
< >	Translation into English of German or Italian speech. For instance, the transcript would be like this *"die Art des Pilzes* <the fungus species>", where German or Italian speech is written in italics and it is then followed by the English translation.
EMPHASIS	Words written in capital letters indicate that the speaker is emphasising the words.
S:	Unidentified student
Ss:	Several or all students simultaneously
T:	Teacher

4.13 Data Analysis: Classroom Discourse

In this study discourse is conceptualized by the theory on Discourse proposed by Gee (1989). The analysis is further guided by the work of Cazden (2001) and Sfard (2008) on classroom discourse and of Planas and Civil (2013) on the concept of language-as-resource. This conceptual framework is also informed by Cummins' theories of bilingual learning (Cummins, 1979, 2000), and by García's heteroglossic ideology of bilingualism (García, 2009). Methodologically, the fact that a pragmatic paradigm framed the study helped to not limit the possible ways in which data could be analysed.

Transcripts obtained by following the procedure indicated in the previous section and integrated with data from classroom observations constitute the rich material on which an in-depth analysis was conducted. The general purpose of this analysis was to make the large number of transcribed dialogues (and field-notes from observation) manageable and usable for answering the research questions.

As a first step, transcripts were uploaded in NVivo software and read. Notes were taken during the reading process in order to decide how to better use the transcripts to answer, in particular, the first two research questions (RQ1 and RQ2), addressing discourse practices that promote opportunities for learning science. The initial notes were then translated into mind maps which were rearranged many times before concluding that a multi-layered analysis was the best choice to extract as much information as possible from the data (as suggested in Braun and Clarke, 2006). The different layers, or levels, of analysis complement each other and enrich the final picture of the phenomenon. The choice of adopting a multi-layered analysis is in line with many studies on talk from sociocultural perspectives (Pastrana, Llinares and Pascual, 2018) and it is motivated by the need to focus on various aspects of the classroom dialogue and to extract as much information as possible from data that usually require a lot of time to be collected and transcribed. This multi-layered analysis is composed by the following three layers, or levels of analysis:

(1) A sequential analysis of classroom activities, reported in the form of activities timelines, which informs and provides a general framework for contextualizing classroom discourse;

(2) A discourse analysis focused on classroom interactions (i.e. questioning and answering);

(3) A thematic analysis of classroom discourse.

A graphic overview of the adopted multi-layered analysis conducted on the classroom talk is illustrated in Figure 4.5.

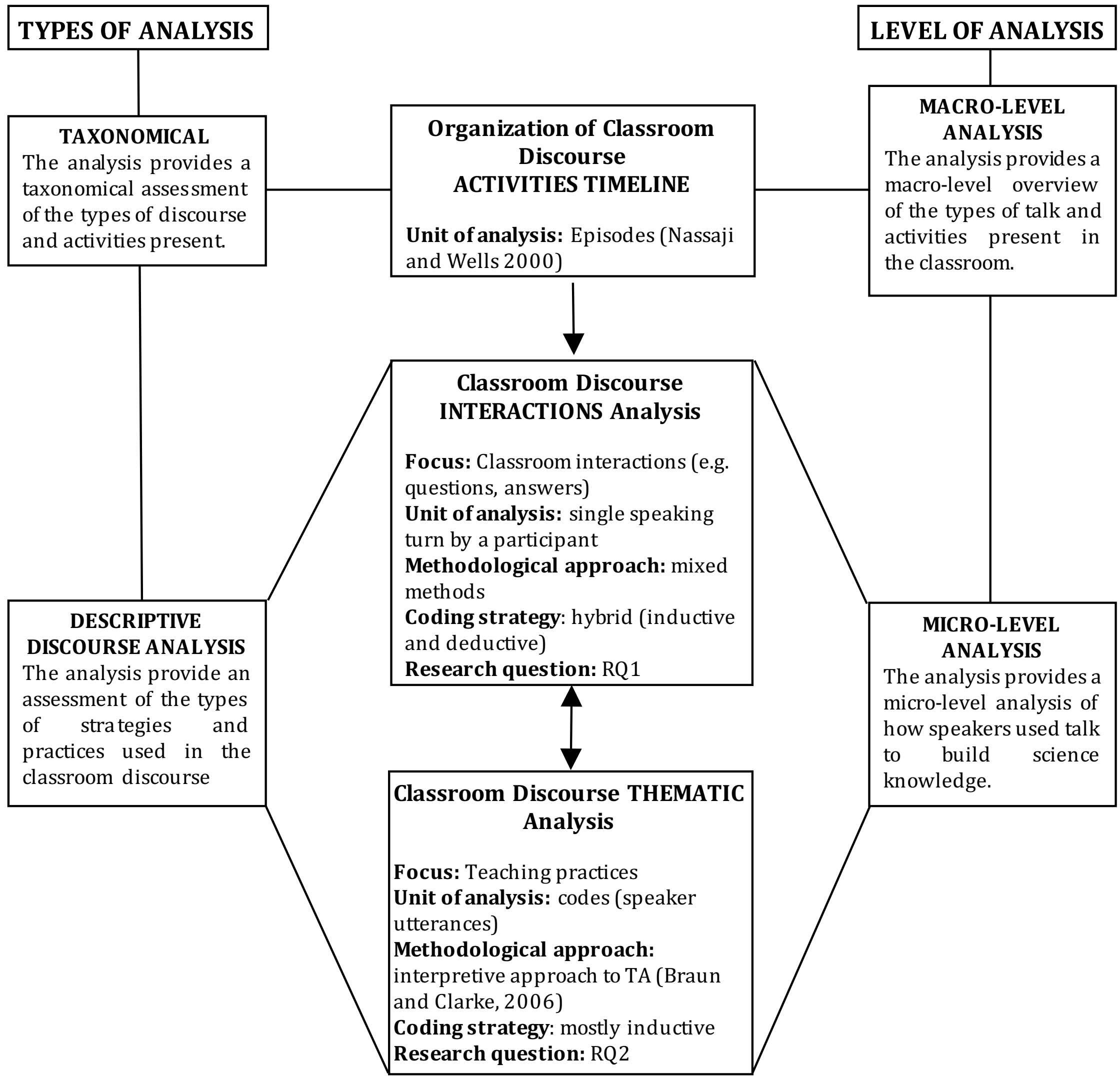

Figure 4.5 Overview of the multi-layered analysis on classroom discourse. Adapted from Brown and Spang (2008, p. 714).

4.13.1 Analysis of the Organization of Classroom Discourse

The analysis of classroom discourse began by constructing *timelines*, i.e. a taxonomical and sequential representations of the classroom activities. These are reported in Appendix D (see also figure Figure 4.6 for a sample of a classroom activities timeline). At this macro-level of analysis, each class period was segmented into activities. These timelines were drawn from field-notes observations integrated with data from transcripts. As a result, each timeline was constructed by illustrating a 50-minute class period. These graphic timelines chronologically listed both activities types—whether whole class, small group, or individual—and dialogue patterns (i.e. monologues, short monologues, whole class dialogues and peer dialogue). Each activity and discourse pattern was reported with indication of the time invested in them. Each segment is given a general cover term. Most of the cover terms used for describing the classroom segments are drawn from Lemke's *Talking Science* (1990); others are added according to the data.

The principal unit of analysis of the timelines are *episodes,* as derived from the work by Nassaji and Wells (2000, p. 11). Each episode corresponds to a distinct task or activity. Changes of activity and shifts in what was discussed, such as the beginning of a new topic or new aspects of the same topic determined episode boundaries (Warfa, Roehrig, Schneider and Nyachwaya, 2014). The timelines offer a sensible visual overview of the range of activities and dialogue formats over time with an approximate length of each. This kind of representation is inspired by an ethnographic study of discourse processes in school science conducted by Kelly and Crawford (1997). In addition, the coverage percentages of the main types of talk across case studies were calculated using the coverage data provided by the NVivo software. NVivo calculates the quantity of text assigned to a particular code (in number of characters) as a percentage of the total source in which the code has been identified (Bazeley and Jackson, 2013). Coverage percentages were utilized because they provide a quick overview of how discourse is organized within each case study (end of Appendix D) .

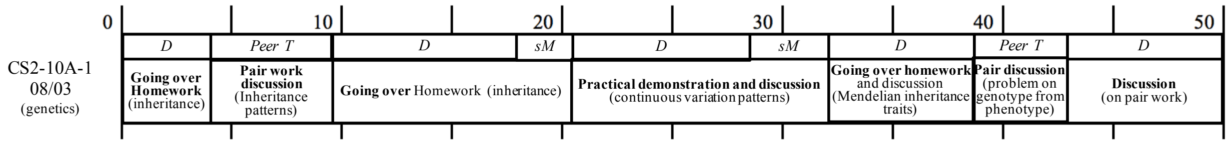

Figure 4.6 Sample of a classroom activities timeline. See Appendix D for the whole set of 34 timelines.

4.13.2 Classroom Interactions Discourse Analysis

As noted by Mercer (2004, p. 141), the term discourse analysis refers to "several different approaches to analysing language (both spoken and written) and to quite different methods". In this study, I adopt a descriptive approach that is focused on the function of the communication (Halliday and Matthiessen, 2004; Lemke, 1990), that considers learning as dependent on discursive practices (Sfard, 2008) and socially constructed through interactions (Vygotsky, 1978). The aim of this analysis is to understand how classroom interactions promote conceptual understanding and science language development. Instead of measuring learning outcomes through ex-post tests, which is preferred in qualitative research studies, science learning is here *reconstructed* from the analysis of classroom interactions. This approach is not new in bilingual science classroom research (e.g. in Bonnet, 2004; Yassin, Tek, Alimon, Baharom and Ying, 2010). In order to extract the highest amount of information from classroom transcripts, these were analysed using a mixed methods approach, i.e. qualitative and quantitative (see Mercer, 2010). Mercer highlights how within this approach, extracts of transcribed talk and their commentaries (as typically presented in ethnography and conversation analysis) are integrated with quantitative analysis. I incorporated the principles proposed by Mercer (2010) by analysing both qualitatively and quantitatively the same data. Essentially, transcripts had been first coded, then extracts of transcripts were integrated in a descriptive and interpretative narrative focused on answering RQ1. Finally, frequencies of categories or codes were used to enhance the understanding of findings. The use of the software NVivo supported this part of the process, as frequencies can be easily retrieved. This quantitative approach to data analysis was particularly useful for comparing occurrences of codes or categories across cases or across the whole data set. Quantitative data were summarised in matrices, which made them more easily accessible for the process of interpretation (Cassell and Nadin, 2008, p. 127). "A matrix is essentially the 'interception' of two lists, set up as rows and columns" (Miles, Huberman and Saldaña, 2014, p. 108), and in this study, they usually take the form of tables (e.g. Table 5.6, in Chapter 5) or are further elaborated into staked chart bars (e.g. Figure 5.3, in Chapter 5). The numbers in the cells of a matrix represent the frequencies by which determined codes occur within a case study or in conjunction with other codes. It is very important to note that the displayed numbers in the matrices produced in this study do not *measure* relationships between variables. Instead, they simply indicate that a certain code is more likely to occur in a particular case study or in conjunction with another particular code.

4.13.3 A Framework for Analysing Classroom Discourse Interactions

A set of categories was constructed based on the research questions, the peculiar classroom setting (CLIL), the literature review, the observations of the classrooms and an initial reading of the transcripts. Categories were either deductively constructed—i.e. derived from literature (Crabtree and Miller, 1992)—or inductively derived (Boyatzis, 1998). Categories were sought among the following dialogue components: (1) teacher questions and feedback (2) students' answers (3) students' questions. Transcripts were coded using categories and codes. Relevant categories and codes for answering research question RQ1 were maintained and checked. The coding process was repeated a second time (Joffe, 2012). During the rereading, new codes were added, some codes were deleted and discrepancies were resolved upon reflection (Braun and Clarke, 2006). The NVivo software facilitated the coding process (Bazeley and Jackson, 2013). In addition, mutually exclusive categories and codes were cross-tabulated in NVivo for inconsistencies and issues were resolved (Maxwell and Chmiel, 2014). The whole set of categories and codes is provided in Appendix E. The units of analysis implemented in classroom discourse interactions analysis were mostly single move in the IRF/IRE sequence, i.e. the single speaking turn by a participant (Nassaji and Wells, 2000). An overview of the analysed components is represented in Table 4.7, where also the key questions that guided the coding process are displayed.

Table 4.7 Components of the classroom discourse analysis implemented in this study.

Component	Key question	References
1. **Teacher Questions and Feedbacks**	What are the characteristics of teacher questioning that promote higher cognitive engagement, verbal production, sensemaking and that monitor students' construction of knowledge? What are teacher's questions that promote science language development?	Chin (2006) Rowe (1986)
	What are the characteristics of teacher's feedbacks that support cognitive engagement, verbal production and sensemaking?	Mortimer and Scott (2003) Chin (2006) Van Zee and Minstrell (1997a)
2. **Students answers**	How do students answer to their teacher in terms of knowledge building, cognitive engagement and language production?	Chin and Osborne (2010a) Barnes (2008) Shavelson, Ruiz-Primo, Li and Ayala (2003)
3. **Students Questions**	How are students' questions promoted/facilitated? How are students' high-cognitive level questions promoted/facilitated? How do students' questions promote conceptual understanding?	Chin and Osborne (2008) Chin and Osborne (2010b) Scardamalia and Bereiter (1992)

This analytical framework was inspired by the "questioning-based discourse analytical framework" developed by science educator and discourse analyst, Christine Chin (2006, 2007). In particular, the deductive coding scheme proposed by Chin (2006) was modified into a more flexible coding approach: partly deductive and partly inductive. The resulting coding scheme focuses on (a) the cognitive demand and function of teacher's questions, teacher's feedback, student's answers and students' questions in relation to their potential to generate opportunities for learning science, (b) how the teacher's questions and feedback minimized linguistic barriers, (c) how communicative strategies supported students' answers and interventions. Teacher questions were classified according to their function within the stream of the dialogue (e.g.

probing, extending, challenging), to the linguistic peculiar setting (e.g. language-related questions) and to their cognitive demand derived from the taxonomy proposed by Anderson and Krathwohl (2001).

The students' answers were classified with a coding scheme that considers cognitive engagement, extensiveness of the answers and communicative strategies (i.e. lexical repair strategies). This coding scheme is partially inductively determined and partially draws on the knowledge framework proposed by Shavelson *et al.* (2003). This framework discriminates between declarative (knowing that), procedural (knowing how), schematic (knowing why), and strategic knowledge (knowing when and how a certain knowledge applies to a new situation). The students' unsolicited initiatives were sorted out according to their purposes in relation to meaning-making processes. Accordingly, students' initiatives were divided into two subcategories: *basic information questions* and *wonderment questions*, based on the categorization of Scardamalia and Bereiter (1992). The former are factual or procedural questions, whereas the latter are pitched at a higher cognitive level and reflect "curiosity, puzzlement, scepticism or a knowledge-based speculation" (Chin and Brown, 2002, p. 524).

An overview of the framework (and coding scheme) applied to the analysis of classroom discourse is displayed in Table 4.8. As mentioned before, this coding scheme is partly deductive and partly inductively derived. In Appendix E a comprehensive list of categories and codes implemented for analysing classroom discourse interactions is provided. Categories and codes emerged from the discourse analysis on classroom interactions are presented and discussed in Chapter 5, where they are analysed also in relation to findings derived from other research components (i.e. teacher interviews and student questionnaires).

Table 4.8 Components and categories for analysing the building knowledge domain of the classroom discourse analysis focused on questioning.

Teacher Questioning and Feedback	**Questioning Functions and Cognitive Demand** (e.g. Lower Order Thinking Questions, Higher Order Thinking Questions, Language-related questions) **Questioning Strategies** (e.g. cueing, wait time, contingent questioning) **Feedback Strategies** (e.g. explicit correction, restating, reformulating)

Students Answering	**Type of Knowledge:** Declarative Knowledge (knowing that) Procedural Knowledge (knowing how) Schematic Knowledge (knowing why) Strategic Knowledge (knowing, where, when and how) **Answering Strategies** (e.g. extended responses, one-word answers, choral answers)
Students Initiatives	**Wonderment Questions** **Basic Information Questions**

4.14 Thematic Analysis of Classroom Discourse

In addition to the classroom discourse interactions analysis focused on questioning, the whole corpus of classroom talk was also investigated through an even finer-grained analysis, i.e. thematic analysis (TA). This is the third level of analysis conducted on classroom discourse transcripts integrated with observations. Whereas the focus of the discourse analysis conducted on classroom interactions and discussed in the previous sections is on interactions (i.e. questions and answers), the focus of TA is on teachers' practices. The two analyses produce different types of information that complement each other and enhance the whole understanding of opportunities for learning science in CLIL classrooms. In particular, a social constructionist TA (as the one proposed by Braun and Clarke, 2006) was used to discover patterns that describe how content teaching is achieved and how language is used for accessing and developing science during sessions of classroom talks.

As an investigative instrument, TA aims to identify themes or patterns of meaning within the data (Douglas, 2002). Clarke and Braun (2017, p. 297) argue that TA is "a method for identifying, analysing, and interpreting patterns of meaning (themes) within qualitative data". Clarke and Braun emphasize how TA is unbounded by theoretical commitments, and in this sense, it is closer to a technique rather to a methodology. Different versions of TA can be employed to analyse data collected across a range of research paradigms, ranging from post-positivist (Boyatzis, 1998) to interpretive (Braun and Clarke, 2006). For this analysis, an interpretive form of TA was chosen to complement the descriptive analysis performed on classroom interactions (previous sections 4.13.2 and 4.13.3).

An interesting feature of this methodology is its accessibility even to novice researcher as it relies on a clearly defined set of procedures (Flick, 2009; Potter and Wetherell, 1987). In terms of trustworthiness of the analysis, TA is conducted following a relatively rigorous procedure that has a built-in checking system meant to provide high-quality analysis (Aronson, 1995; Braun and Clarke, 2006; Braun and Clarke, 2012; Braun and Clarke, 2013).

4.14.1 Thematic Analysis: Approach and Procedure

In TA, codes are the smallest units of analysis, the building blocks for themes. Codes can inductively emerge from data (Boyatzis, 1998) or be deductively derived from a predetermined codebook (Crabtree and Miller, 1992). In any case, codes are subsequently analysed for their potential to cluster around themes. Themes are the larger units of patterns of meaning, which share a common organizing principle and provide a framework for systematizing the analysis (Clarke and Braun, 2017).

For this study, I implemented a *mainly* inductive approach to thematic analysis. This means that codes and themes are grounded in the data as in grounded theory (Glaser, Strauss and Strutzel, 1968). However, by contrast to grounded theory, that aims to develop a novel theory to describe the findings, a thematic analysis aims to summarise data into themes that are then explained (Ryan and Bernard, 2000).

As already mentioned, the approach was predominantly but not exclusively inductive because even though the coding process was basically grounded in the data, the researcher drew on theoretical constructs from science education and language learning, as illustrated in section 3.7. In particular, codes that relate to the use of metadiscourse in the classroom talk were entirely derived from literature. By contrast, most of the other codes were data-driven and some *in-vivo* coding was also applied. Bringing elements of deductiveness into an inductive process and vice versa is common in Thematic Analysis (Braun and Clarke, 2012, p. 59).

For implementing TA, the procedure proposed by Braun and Clarke (2006) was followed, this include: (a) familiarising with data; (b) generating codes; (c) searching for themes by collating codes, (d) checking, reviewing and refining. This entire process was facilitated by using the NVivo software.

The TA applied to the classroom transcripts of this study resulted in five core themes emerging. Table 6.1 (in Chapter 6) provides a full list of themes and relative codes.

4.14.2 Generating Codes

Data from the classroom transcripts were analysed for codes that resonate with the research question RQ1, addressing discourse practices that promote opportunities for learning science. In this study, data were approached with specific questions in mind and with a structured theoretical framework that backed up the study. From the very beginning, it was clear that a double focus, i.e. language *and* content, i.e. science learning, had to guide the analysis. However, while the general issues of the study were predetermined, codes and themes were not decided prior to coding the data, but emerged during the analysis (Douglas, 2002). Accordingly, transcripts were coded adopting a predominantly inductive approach. This meant that the researcher tried to stick to the raw data as close as possible, while knowing and accepting that the coding process is sensitive to projection on the part of the researcher.

The coding was conducted by one person only (the author). In order to increase the reliability of the analysis, more people could have been involved in this phase of the procedure (i.e. inter-rater checks, Lewis and Ritchie, 2003). However, as the goal of this work is not to guarantee the systematic use of a code book, or the generation of one, inter-rater reliability checks is less relevant to the kind of interpretive process that is central to this thematic analysis (Braun and Clarke, 2016). In addition, classroom transcripts are an unstructured data source, from which a researcher learns as the coding process progresses. In this situation, Morse (1997, p. 446) argues that a second coder would probably contribute to increasing the general reliability of the study at the high cost of "losing all the richness and creativity of the analysis". Nevertheless, reliability is not an alien element to this study. As the analysis was conducted by one person only, reliability was addressed in other ways. For instance, multiple cycles of reading, coding and examining the data also enhanced the general quality of the analysis (Baralt, 2012). Discrepancies between repeated sessions of analysis on the same segments of data were pondered and codes were revised. The checks on discrepancies implemented the internal reliability of the whole analysis (Guest, MacQueen and Namey, 2012). Reliability was also addressed through an aspect of reflexivity, which Seale (1999, p. 158) describes as "the process of showing the audience of research studies as much as is possible of the procedures that have led to a particular set of conclusions".

Most of the codes that emerged are semantic, or descriptive ones, meaning that they merely describe the content of the data. In other words, they are limited to a factual level of analysis. An example of this is *asking for translation*. A few interpretive, or latent codes emerged too, even though they are rare. These codes identify meanings that are beneath the semantic surface of the data (Braun and Clarke, 2012). An example of this is *epistemology marker*, which offers a conceptual interpretation of what the teacher is saying. In educational research, having a mixture of both types of codes —descriptive and interpretative —is not infrequent (Cohen *et al.*, 2011).

4.14.3 Searching for Themes

When the transcripts were all fully coded, the codes were collated to search for themes across the data during an iterative process, and clustered under headings to reflect the research questions.

A theme is a construct that “captures something important about the data in relation to the research question, and represents some level of *patterned* response or meaning within the data set” (Braun and Clarke, 2006, p. 82). A theme can be represented as a thread of underlying and often latent meaning throughout codes (Graneheim and Lundman, 2004). The searching for themes was an active process modelled on the emerged codes, the research questions and the theoretical framework. The researcher looked for *data-grounded* themes as well as *anticipated* themes. Since data have potential multiple meanings, a coded strip of text can fit into more than one theme (Downe-Wamboldt, 1992).

Themes were developed around clustered codes. The use of visual thematic maps was implemented to facilitate the clustering of categories into themes. Through the drawing of lots of thematic maps, five themes were generated. Overall, the expected result was the discovery of a coherent and meaningful pattern in the data and the themes provided the best mapping of the data in relation to the research questions.

Themes and codes from the thematic analysis conducted on classroom discourse are presented and discussed in Chapter 6, where they are also analysed in relation to findings derived from other research components (i.e. teacher interviews and student questionnaires).

4.15 Analysis of Teachers’ Interviews

4.15.1 Transcripts Production

Verbatim transcripts were produced on the three interviews with the teachers. The transcript production followed the same general criteria as the transcript production of classroom discourse (section 4.12). In this case, the focus was decisively on the content of the communication. Accordingly, these transcripts retained less information than the transcripts of the classroom talk. For instance, wait time and pauses were not marked as they were not relevant for answering the research question that underpinned this part of the research process, i.e. the epistemological beliefs and teaching goals of teachers.

4.15.2 Thematic Analysis

An inductive approach to thematic analysis, i.e. data-driven, was implemented for identifying recurrent themes in the three interviews with the teachers (Braun and Clarke, 2006). Data from the interview transcripts were analysed for codes that resonated with research question RQ4, addressing teachers' goals and epistemological beliefs about teaching science through a CLIL approach.

This analysis was done across questions, rather than for each open-ended question individually, in order to identify commonalities running through the data as a whole. The general procedure for analysing interview data reflected what was suggested by Crisp (2000). First, transcripts were coded by analysing them line by line or word by word, by interpreting each segment of data and by making comparisons for similarities and differences. This was done in regard to issues relevant to the investigation. Repeated rounds of reading and data categorising made it possible to extract three themes. The themes were verified or revised after re-checking the transcribed interview data through repeated investigation of patterns of commonalities (Potter and Wetherell, 1987). Themes and codes from the thematic analysis conducted on teacher interviews are presented and discussed in Chapter 5 and Chapter 6, where they are analysed and integrated with findings derived from other research components (i.e. classroom discourse and student questionnaires).

4.16 Analysis of the Questionnaire

The quantitative data consisted of 160 questionnaires filled in by the students of the three case studies during the school year 2016/2017 (see Appendix B for the questionnaire text). All questions were given a unique code and responses were entered in SPSS (Version 23 for Mac) using these codes. The reliability of the scales was assessed statistically by obtaining the Cronbach's alpha scores for each of the 7 scales. Cronbach alpha scores provide an indication of the average correlation among the items that make up a scale, with higher values indicating greater reliability (Pallant, 2011). In five out of seven scales, the Cronbach alpha values of the questionnaire scales indicate "respectable" to "very good" reliability (greater than 0.7) for most of the scores (DeVellis, 2016). This reveals a good internal consistency of most of the scales. The results from the two scales with low Cronbach's alpha score were interpreted more cautiously.

A descriptive statistical analysis was conducted on the data. In particular, median scores from the Likert scales of items were calculated. Median scores are preferred to mean scores as a measure of central tendency because the collected ordinal data do not follow a classical normal distribution (Sullivan and Artino, 2013). In particular, the frequencies of some of the items have highly skewed distributions (e.g. most of the items in the *Personal relevance* scale, *Uncertainty of science* scale, *Science learning in a second language* scale and *Anxiety and enjoyment* scale"). Accordingly, the interquartile range (IQR) served as a measure of the variation of data, instead of the standard deviation (Larson-Hall, 2015). The IQR was calculated as the difference between the third quartile and the first quartile (Bryman and Cramer, 2005, p. 105), where the third quartile (Q3, or P_{75}) is the value below which 75% of the values fall, and the first quartile (Q1, or P_{25}) is the value below which 25% of the values fall. In addition, single items frequencies were analysed and interpreted both across the whole data set and across case studies. Frequencies of single items across case studies and across the whole data set were graphically represented by stacked bar charts. Some of these charts resulted relevant for answering the research questions. Accordingly, they are presented and discussed in the next chapters.

Overall, the results of the questionnaire responses contribute to answer research question RQ4, addressing students' perceptions. These are presented and commented along with findings derived from other data sources and analysis types (e.g. teacher interview and transcribed classroom talk investigated through thematic and discourse analysis). This choice was considered the most efficient one because the aim of processing and analysing data resulting from the questionnaires was not to generalize about students' perceptions (the population would be far too small for that purpose), but to get a more complete and informative picture of opportunities for learning science in CLIL classrooms and to enhance the whole validity of the study through triangulation of different data (Denzin, 1970; Denzin, Lincoln & Giardina, 2006).

The results from the statistical analysis of the questionnaire's responses are presented and discussed in Chapter 5 and Chapter 6, where they are analysed and integrated with findings derived from other research components (i.e. classroom discourse and teacher interview).

4.17 Data Integration

Data integration is the process that merges what has been discovered in the previous analysis phases into one coherent piece (Li, Marquart and Zercher, 2000). In this study, findings that emerged from the separate analyses of different research components were integrated in the interpretive final phase of the analysis (as indicated in Figure 4.2). In particular, the findings from (a) the discourse analysis on classroom interactions, (b) the thematic analysis of classroom discourse, (c) the thematic analysis on teacher interview and (d) the descriptive statistical analysis on questionnaire responses were compared in search for commonalities that could relate one part of the research with another and provide a mutual explanation, or a deeper and multi-faceted understanding. In this way, different sources of data, both qualitative and quantitative, where compared and integrated around a few key findings, supported not just by one form of data, but by the combination of various data sources. For instance, some of the themes emerged from the analysis of the transcripts told a story that had common patterns with some dimensions investigated using the questionnaire. In these cases, findings from different sources were compared and a final fuller and more coherent understanding of that particular research element was achieved. Figure 4.7 illustrates how different sources of data and forms of analysis connected with each other. Chapters 5 and 6 explain how the integration between findings from different sources of data was achieved.

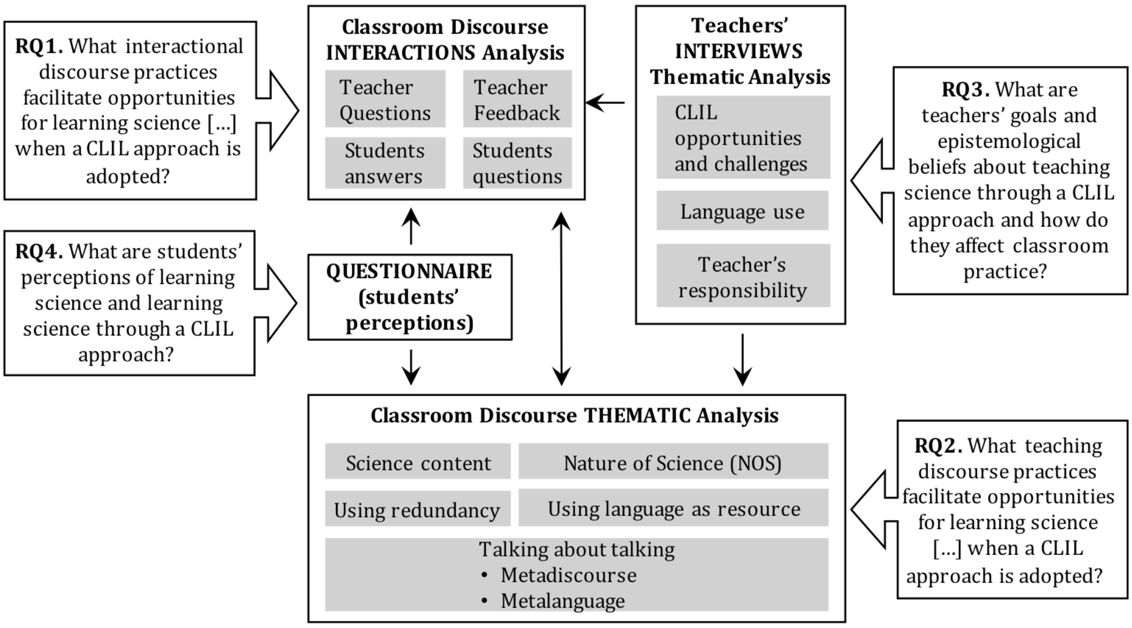

Figure 4.7 Relationships between different forms of data sources, analyses and research questions.

4.18 Research Validity and Reliability

Validity and reliability were assessed by referring to qualitative and quantitative criteria (Creswell and Clark, 2007; Teddlie and Tashakkori, 2003) and to Yin's suggestions (2009) for case studies. Whereas validity refers to the truthfulness of findings, reliability refers to the stability of findings (Altheide and Johnson, 1994). According to Cohen *et al.* (2011), invalid and unreliable research serves no purpose. The following sections provide an overview of each construct as relevant to the study undertaken.

4.18.1 Validity

Generally speaking, valid research is “plausible, credible, trustworthy, and therefore, defensible” (Johnson, 1997, p. 282). Similarly, Sandelowski (2003), treats the term validity and trustworthiness as synonyms. Table 4.9 provides an overview of measures taken to support validity in each research phase of this study.

Table 4.9 Qualitative validity and reliability, tactics adopted and research phases involved. Modified from Yin (2009, p. 40).

TESTS	Research tactic	Phase of research
Construct validity	- Theoretically frame and inform every research component with suitable and reputable sources and theories	Literature review Research design Findings interpretation
Internal validity	- Naturalistic fieldwork observations - Fairness and integrity in conducting interviews - Audio-recordings of interviews - Audio-recordings of classroom discourse - Cross-check of transcripts with observational note - Transcription and coding close to raw data - Transparent and thorough presentations of findings - Integrity and fairness in interpreting findings - Checking discrepancies between findings	Data collection Analysis Findings interpretation Transparency in the writing
External validity	- Replication logic (in sampling of cases)	Research design
Content validity	- Extensive and comprehensive literature review	Literature review
Reliability	- Stability of data collection (e.g. semi-structured interview, classroom observations schedule) - Seeking for theoretical saturation of collected data - Developing framework for analysing classroom discourse - Using thematic analysis (rigorous procedure) - Multiple checks (repeating coding, resolving discrepancies) - Cross-checking findings	Data collection Analysis

4.18.2 Qualitative Validity

The validity of qualitative and quantitative components of this study are addressed separately. The adopted categorization (as illustrated in Table 4.9) follows what suggested by both Cohen *et al.* (2011, chapter 10) and Yin (2009, chapter 2).

Construct validity is broadly defined as the extent to which an operationalization measures the concept it is supposed to measure (Cook and Campbell, 1979). It ensures that the author's theoretical understanding is in line with what is generally accepted (Cohen *et al.*, 2011). To ensure this, the study was conceptually framed by suitable and reputable sources and theories, that were organised in a comprehensive and organic theoretical framework.

Internal validity ensures that the "findings accurately describe the phenomena" and conclusions resulting from the analysis can be sustained by data (Cohen *et al.*, 2011, p. 183). Internal validity is threatened when undertaking the investigation itself affects the behaviour of the participants in the study (Drake and Heath, 2010, p. 37). In this study, internal validity was addressed in different ways. First, while observing the classes, the researcher tried not to alter the natural environment as best as she could. Some measures that were adopted in this regard are described in section 4.9.1. Second, during the interviews with the teachers, leading questions and comments were avoided and a genuine interest in only listening to the interviewee was sought. In addition, interviews were audio-recorded. Third, classrooms' observational notes were always integrated with audio-recordings and the two sources of information were cross-checked. In terms of analysis, the transcription and the coding process were accomplished trying to stick as close to the raw information as possible. Findings were presented using an abundant display of extracts and interpretation was accomplished by trying to never lose sight of the data and of their original meaning. Reported extracts were commented by avoiding to treat "anecdotal illustrations" as evidence (Pelto and Pelto, 1978, p. 226), and any alternative explanations were considered and accordingly reported. It is still possible that the researcher simply did not come up with the most plausible or correct explanation, however the insight and the experience of an attentive supervisor greatly improved this sensitive phase of the analysis. Finally, findings from different sources of data were compared where possible and discrepancies neatly reported.

External validity refers to how data are collected and analysed and can be generalised for the wider population (Drake and Heath, 2010). One of the characteristics of qualitative research that is most criticized especially by proponents of a quantitative approach in empirical social science research, is the lack of external validity or generalizability (Verschuren, 2003). This is particularly true for case study research (Bassey, 2000). However, while referring to classroom research, Lemke (2011, p. 1480) challenges the value of generalization as "human communities and cultures are often more interesting for what is unique to them than for what they all have in common." It appears that even though case studies offer a poor basis for generalizing, maybe aiming at generalizing is not all what research should be about. In this study, external validity is established through another way, i.e. through *literal replication*. Yin (2009, p. 54) explains that replication logic in multiple-cases study is analogous to what researchers do in multiple experiments, where the conditions of the original experiment are replicated in the next experiments. In this study, the samples are three case studies which have been purposefully chosen, as explained in section 4.8. The three cases were selected so that each of them potentially predicted similar results in relation to the research questions. This is the condition that Yin defines as literal replication.

Content validity ensures the author is fair and comprehensive with respect to the research problem. This research draws upon an extensive literature review, that involved reviewing different bodies of literature, so that all possible perspectives of the issue were covered and a gap in the research was identified.

4.18.3 Quantitative Validity

In general, the validity of quantitative research components can be improved through careful sampling, appropriate tools for collecting data and appropriate statistical analysis of the data (Cohen *et al.*, 2011). In this study, the measurement tool implemented for collecting quantitative data (i.e. the questionnaire) incorporated scales that had been previously and repeatedly validated by many authors (as reviewed by Fraser, 2014). The new scales were conceived for this study through a thorough analysis of the existing literature about the constructs of interest and by a rational analysis of the instrument by experts familiar with the research subject and educational surveys. In addition, the questionnaire was tested in the pilot phase and amended as explained in 4.10. This ensured that no item was likely to cause any problem during further administrations. The questionnaires were always administered in class in the presence of the researcher or of the teacher, which ensured that any issue about comprehensibility was solved before any questionnaire was returned. Many items' responses did not have a normal distribution; therefore, the statistical analysis was treated carefully, as explained in section 4.16.

4.18.4 Reliability

Leedy and Ormrod (2001, p. 31) define reliability as "the consistency with which a measuring instrument yields a certain result when the entity being measured has not changed". As stated by Wiersma and Jurs (2009, p. 9), the reliability of a study refers to whether or not "independent researchers can replicate the study". The reliability tactics implemented in this study are outlined in Table 4.9. Given that a mixed methods approach to data collection and analysis was applied to this research, both quantitative and qualitative reliability were considered. In general, adequate levels of reliability were ensured by using consistency and replicability with regard to data collection procedures, test instruments and analysis within each research element. In particular, in the data collection phase, qualitative reliability was addressed by using a classroom observations schedule and semi-structured interviews. In the analysis, qualitative reliability was enhanced by adopting a framework for analysing classroom discourse interactions (described in section 4.13.3) and by using thematic analysis for analysing classroom discourse and interviews, which is a rigorous procedure with a built-in checking system (Braun and Clarke, 2006). Reliability was also established by multiple cycles of coding, repeated checks and reflexivity (Seale, 1999, p. 158) and improved by carefully designing and assessing data collection.

Quantitative reliability applies here to the use of a questionnaire to collect students' perceptions. The reliability of a questionnaire is the extent to which the test instrument produces the same results on repeated trials. In short, it is the stability or consistency of scores over time or across raters (Bolarinwa, 2015). In this research study, the reliability of some of the scales used in the questionnaire was assessed in previous studies (see Dorman, 2003; Fraser, 1981; Fraser, Fisher and McRobbie, 1996; Taylor, Fraser and White, 1994). In any case, the internal consistency of the implemented scales was assessed using the Chronbach's alpha coefficient.

4.19 Triangulation

The implementation of a number of sources for data collection, as in this project, is referred to as triangulation (Webb, Campbell, Schwartz and Sechrest, 1966). The concept of triangulation is "based on the assumption that any bias inherent in particular data sources, investigator and method would be neutralised when used in conjunction with other sources, investigators and methods" (Creswell, 1994 p. 194). Therefore, triangulation enhances both reliability and validity. In this study, methodological triangulation was employed, meaning that a number of different data collection methods were used (Lincoln and Guba, 1985). Figure 4.8 outlines methodological triangulation in this study, with different sources of data collected using different methods.

It is important to note that mixed methods were not implemented in this study to corroborate one set of results against the other, but to achieve a more comprehensive understanding of the target phenomenon, in other words to achieve what Torrance (2012, p. 112) describes as "a fuller and more informative picture of what is going on: such fuller pictures will be more rounded, nuanced and valid than that produced by a single method". Strictly speaking, because this research does not specifically aim towards convergent validity, some authors would not apply the label triangulation to any part of its process (Sandelowski, 1995, 2003). However, some *incidental* forms of convergent validity were obtained when comparing and integrating findings from different sources. In section 6.8.6, it is illustrated one of these events.

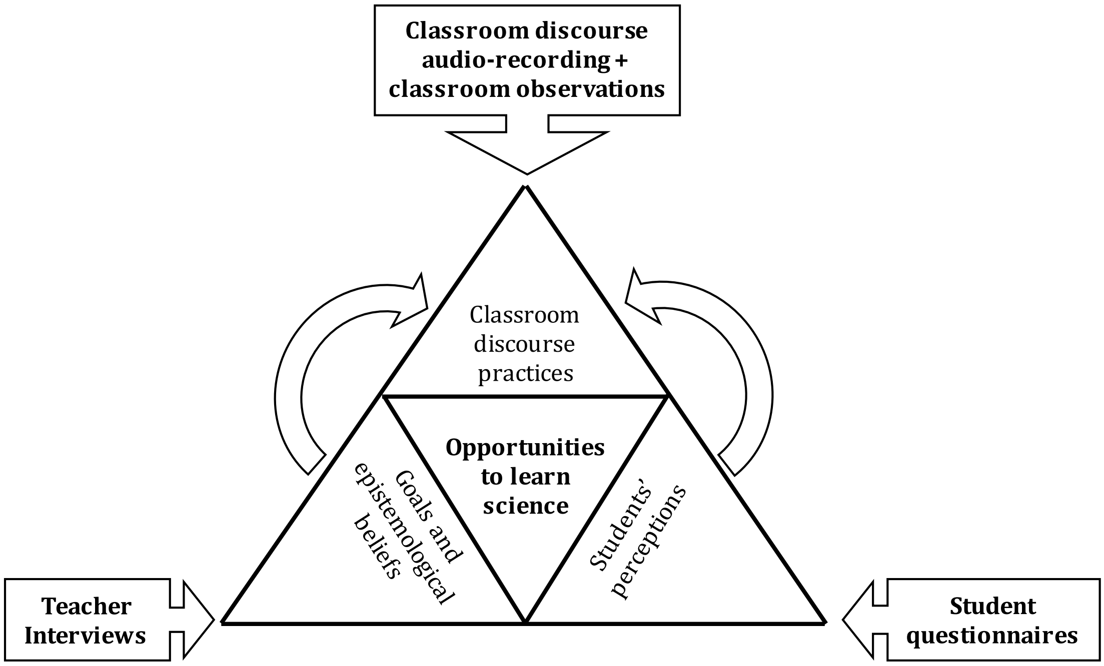

Figure 4.8 Triangulated data collection methods for the research components of this study. Adapted from Oliver-Hoyo and Allen (2006).

4.20 Ethics

The study received full ethical approval from the Research Ethics Committee of NUI Galway in January 2016. In addition, access and interventions to the German schools was specifically approved by the local departments of education. For this purpose, complementary ethics approvals were requested and obtained in Hamburg and Berlin.

The informed consent and assent forms constructed for this study and information sheets were either in German (Hamburg and Berlin) or Italian (Trento). Information sheets outlined a description of the study, implications for participants and data protection measures. If students were willing to participate in the study, they were required to sign the informed assent form and the signature of a parent/guardian was also required prior to taking part in the study with the exception of the participants from Berlin (CS2). In this German district, students older than 14 do not require parental/guardian consent as per regional law. Participation could be withdrawn at any time. Student questionnaires were anonymous and all true names of students and teachers that appeared in the audio-recordings were changed into pseudonyms. Schools' names were never mentioned and never will be. Confidentiality is ensured through secure storage of data for five years following study completion, which is consistent with NUI Galway guidelines. A copy of the information sheet and informed consent form in English is attached in Appendix F.

4.21 Researcher distance

As discussed in Chapter 1, my professional experiences as CLIL biology and chemistry teacher contributed to my decision to pursue a research project in the field of science education when a CLIL approach is implemented. However, my background and my profession can be both an asset and a liability. A liability because, as a result of my professional role, it is expected that I bring my own biases, assumptions and expectations to the project. Consequently, as any professional undertaking research I "must, despite starting from a position of knowledge and insight into what is important, take extra care to rebut attacks for not being sufficiently distant and therefore critical" (Drake and Heath, 2010, p. 19).

In order to develop a sufficient critical distance, an extensive engagement with literature helped me to reconsider my preconceived assumptions. Moreover, my biases were also mitigated by the adoption of diversified methods of data collection that brought different perspectives to study. More importantly, the acknowledgement of my biases and expectations helped me to establish researcher's distance and objectivity. In addition, recognising the play between doctoral researcher and professional practitioner promoted the development of my own critical reflexivity in every aspect of the research and writing process.

On the other hand, my experience as professional practitioner helped me to design the investigative tools I implemented, to be considerate with student and teacher participants, to interpret the classroom dynamics and curricula implications more deeply.

4.22 Methodological Limitations of the Study

Some limitations of this study are inherent in the research paradigm and in the research design. At some point, I needed to interpret what the participants had shared with me and, as Treagust, Won and Duit (2014) point out, the research participants share only what they want to share and this affects both qualitative *and* quantitative data. In addition, there is always the risk of projecting your own values and beliefs onto others (Freud, 1985). The familiarity with the phenomenon being studied has, as Boyatzis (1998, p. 13) says, "a curvilinear relationship with encouraging projection". Therefore, my interpretation of phenomena and data was *heavily* influenced by my own professional and cultural experiences. Even if having a good understanding of the educational phenomenon was usually an asset in my hands, the same became a liability when it influenced my interpretation. The adoption of tactics as the one described in sections 4.18.2 (validity) and 4.18.4 (reliability) prevented or lessened the contamination by projections both while collecting data and while analysing them.

Another possible methodological limitation of this study is the relatively small number of lessons observed. However, this could not have been increased. Although the quantitative part of this research (i.e. the questionnaires) would have greatly benefited from this, the qualitative part would have become unmanageable as more hours of observations would have meant more hours of transcription, more coding and analysing.

In the research design phase, the three participating schools were carefully sampled to reasonably represent science learning with a CLIL approach at upper secondary level. As a result, the three case studies investigated included a range of students with similar academic ability and English proficiency. On one hand, this was a sought and welcomed condition. On the other hand, this condition greatly limits the potential to generalize from the results.

4.23 Conclusions

The aim of this study is to contribute to the science teaching practice with a deeper understanding of the dimension of science learning when a CLIL approach is implemented. The purpose of this investigation is to examine how opportunities for learning science are promoted in the classroom discourse of upper secondary science classrooms when a CLIL approach is adopted. This chapter presented how this purpose was achieved. In particular, it was outlined how and why a multiple-case study design was chosen and a mixed methods approach to collecting and analysing data was implemented. A detailed account of the sources of data (namely classroom discourse, classroom observations, teacher interviews and students' perceptions), of how these were collected and interrogated was also provided. Each research component was justified in relation to the research questions and to the theoretical framework of the study. The researcher's concerns with regard to validity, reliability, ethics and researcher distance were also acknowledged. Research findings will be presented and discussed in the next two chapters.

Chapter 5 Building Science through Classroom Discourse

The more complex it gets and the more they have to explain and give their own ideas, the more difficult it becomes for them to participate in English. If they only have to describe, or repeat, or revise that would be relatively easy for them, but to give opinions, speculate... that's another thing.

[Emma, CS2 teacher]

5.1 Introduction

The main focus of this chapter is on whole-classroom interactions. The aim is to present and concurrently discuss the findings that emerged from the interaction analysis of classroom discourse in order to understand how these interactions contribute to generating opportunities for learning science in CLIL classrooms when a teacher and their students are engaged in asking and answering questions.

For the purposes of this analysis, classroom talk transcripts were first complemented with data from classroom observations. Subsequently, these were coded and analysed for the emergence of participatory conceptual understanding and science language development, which are considered the constitutive elements of the theoretical construct of opportunity for learning science in this study (as explained in section 3.7.10). To support findings from the analysis of classroom discourse, results from the analysis of the questionnaire administered to the students and from the thematic analysis of the teacher interviews are also used and combined.

In terms of organization, the chapter first introduces the findings about teachers' goals and beliefs extracted from the thematic analysis conducted on teacher interviews, which mainly answers research question RQ3. Second, results from the descriptive analysis of the questionnaire responses about students' perceptions are briefly presented for their relevance to research questions (in particular, to research question RQ4, addressing students' perceptions about learning science through a CLIL approach). Third, findings from the interaction analysis of classroom discourse are presented and discussed in relation to findings from other research components and to existing literature in the research area. A general overview of this organization is presented in Figure 5.1. The presentation of findings about classroom interactions is organised around the main categories of interactions that emerged from the analysis of classroom discourse, namely teacher's questions, students' answers and students' unsolicited questions.

Finally, the chapter closes with some implications for teachers' practice and considerations about the significance of the study. The chapter contributes to answer all three research questions. The next chapter complements the presentation and discussion of findings by shifting focus from classroom interactions to teaching practices.

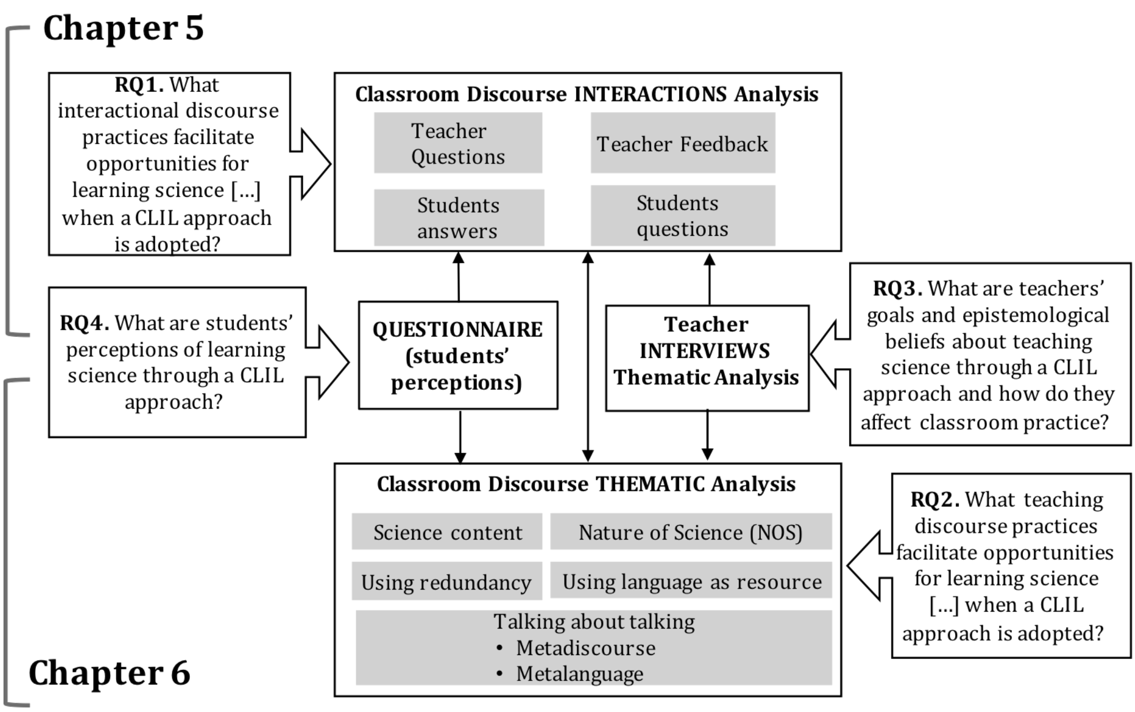

Figure 5.1 Overview of how analytic tools relate to research questions and between themselves in the two thesis chapters dedicated to presenting findings.

5.2 The Analysis of Teachers' Interviews

This section presents and discusses some of the findings derived from the thematic analysis conducted on the three semi-structured teacher interviews. The findings from this analysis mostly answered the third research questions (RQ3), addressing teachers' goals and epistemological beliefs and how these affect classroom practices.

The codes identified in the analysis were collated into three themes. These are: (a) CLIL opportunities and challenges, (b) language use, and (c) teacher's responsibilities, as illustrated in Table 5.1.

Table 5.1 Themes and codes extracted from teacher interviews.

(1) CLIL opportunities and challenges

CLIL *learning* opportunities and challenges:

- opportunity for better learning
- opportunity for life
- linguistic challenge
- changing attitudes and motivations

CLIL *teaching* opportunities and challenges:

- Science teacher or language teacher?
- Teaching opportunities
- Teaching challenges

(2) Language use

- Speaking for explaining
- Speaking for participating
- Listening for understanding
- Knowledge transfer (L2 to L1)
- L1 using

(3) Teacher's responsibility

- Adapting to students needs
- Looking for feedback
- Making science more accessible
- Science language teaching
- Repeating

The outcomes that describe what teachers' goals and beliefs are in relation to the CLIL approach in general are presented in the following section. By contrast, findings that relate to specific classroom practices are presented later, in this chapter and in Chapter 6, in conjunction with findings from other data and forms of analyses.

5.2.1 Teachers' Goals and Beliefs about Opportunities and Challenges

As evidenced by the analysis of teacher interviews, it was found that all three teachers see themselves predominantly as science teachers and basically share similar science teaching goals:

> My general goal is that first of all—first and foremost they have to understand the science. So, as a science teacher, as a subject teacher my primary goal is that they can cope with the content and the understanding and then secondary is the fact that we are doing it in English.
>
> [Alexandra, lines 40-44]

Teachers also share a typical science teaching culture:

> We did a lot of practical work, even if our labs are not well equipped and I hardly have time between the lessons to get them ready. [...] I think that's necessary. [...] you have to spend a lot of time on them. However, I still place great value in doing labs.
>
> [Emma, lines 29-37]

Overall, having taught for years through a CLIL approach has not modified the professional identity of these science teachers. This finding is consistent with the results from a Dutch study which analyses the instructional goals of CLIL practitioners (van Kampen *et al.*, 2017, p. 10).

From the analysis of the first theme—addressing teachers' and students' opportunities and challenges—it transpires that teachers unanimously consider the CLIL approach to science teaching as an opportunity for their students to acquire and improve a skill for life. This skill is not the acquisition of a foreign language *per se*, but rather the ability to learn *through* a foreign language (CS1 and CS2) or to freely communicate as citizens of the world in any context (CS3). This finding confirms what Hüttner *et al.* (2013, p. 276) found about content CLIL teachers, who refer to the construct of the target language "as a means of communication where no other shared L1 is available".

In addition, Alexandra (CS1) thinks that teaching through a CLIL approach offers her an opportunity to better focus on language and literacy:

> I think actually it's a great opportunity because […] you are delivering it in a foreign language that you have to look at language a lot more. That's something you sometimes forget a little bit more when you are teaching in a native language.
>
> [Alexandra, lines 99-104]

The adoption of a CLIL approach is also perceived as a challenge by all three teachers. The specific reasons are different but they are all rooted in language-related issues:

> […] one of the most challenging things I have to face is preparing lessons for students with low linguistic proficiency […] The poorer the students' English is the more demanding is the process of adapting materials.
>
> [Emma, lines 118-126]

> [students] can get lost in the language […] and so one of my greatest compromise is […] trying to balance the quantity of the material with the quality.
>
> [James, lines 75-80]

> […] my greatest challenge was […] to respond to the bilingual nature of the kids […] through the years I've gained more experience to see where they are linguistically […].
>
> [Alexandra, lines 18-27]

5.2.2 Teachers' Epistemological Beliefs about Language and Teaching

Concerning the second theme—addressing the classroom use of language—all teachers consider both the development of conceptual understanding and the active participation in classroom discourse at some risk because of the language factor. Their perspectives on how they view language differ. The findings from the analysis of this theme provide an insight into the teachers' epistemological beliefs about language in relation to the importance of speaking for learning science (presented in section 5.9) and in relation to the bilingual dimension of language (presented in the next chapter, section 6.8).

In relation to the third theme, concerned with the responsibilities of science CLIL teachers, all three teachers believe that it is their task to make science more accessible by focusing more on language. As they conceptualize language in different ways (see section 5.9), they also emphasise different aspects of the teaching practice and propose different solutions. For instance, Alexandra and Emma mention code-switching, adapting to students' needs and intense planning. James believes in reducing the quantity of topics in favour of quality, in repeating and testing frequently. These findings are further discussed in Chapter 6, where teaching strategies are closely analysed.

To conclude, all the CLIL science teachers of this study see themselves as science teachers and share typical science teaching goals. They all acknowledge the linguistic element that the CLIL approach brings into their everyday teaching and interpret it as an opportunity for both their teaching practices and their students' education. These findings contribute to answering RQ3, concerning teachers' goals and beliefs. How teacher's epistemological beliefs affect specific classroom practices is analysed in other parts of this and of the next chapter, where findings from different research components are integrated and discussed together.

5.3 Students Perceptions about Learning Science through CLIL

This section presents and discusses some of the findings emerging from the descriptive statistics analysis conducted on the questionnaire administered to a total of 160 students from the three case studies. A copy of the questionnaire is available in Appendix B. Characteristics of scales and an analysis of the reliability of scales are discussed in section 4.16.

The aim of this investigative tool was to collect information about how students perceive science learning through a CLIL approach with a focus on the instructional practices they are exposed to. Perceptions are here understood in terms of how the learning of science appears to the students and how they perceive and experience it. As perceptions affect both emotions and behaviours (Tacca, 2011), they play an important role in shaping cognitive processes (Goldstone and Barsalou, 1998) and, ultimately, science learning opportunities. The findings from using this investigative tool directly answer the research question RQ4, addressing students' perceptions about learning science through a

CLIL approach. In addition, data from the questionnaire were integrated with findings from other sources (classroom talk transcriptions and teacher interviews) and contributed to producing a fuller and more informative picture of the investigated phenomenon (Thurmond, 2001). Furthermore, the alignment between questionnaire results and findings from classroom discourse reinforces the validity of the study (Denzin, 1970; Denzin, Lincoln & Giardina, 2006).

Overall, responses across case studies reveal that most of the students in all three case studies perceive themselves as actively involved in the process of science learning. They perceive that the science they are learning is related to their everyday out-of-school experiences, that science explanations are accessible. They do not feel threatened by the CLIL setting and they normally perceive the assigned tasks as non-demanding. Most of the scales show results that are consistent across case studies, with the notable exception of the items referring to the use of the first language in class. This result is discussed in the next chapter, section 6.8.6, in conjunction with findings from classroom discourse.

5.4 Focus on Classroom Discourse

The third research component that this chapter examines is classroom discourse. Data about this research component consist of classroom transcripts complemented with field observations. In this chapter, classroom discourse is analysed with a focus on classroom interactions. Discourse is conceptualized here by the theory on Discourse proposed by Gee (1989) and the analysis is theoretically framed within a sociocultural perspective of teaching and learning science. As explained in section 4.13.2 of the methodology chapter, the aim of the analysis is to explore how opportunities for learning science are promoted and facilitated by discourse practices. The analysis used for achieving this aim is a mixed methods approach to discourse analysis (cf. Mercer, 2010). In the next chapter the same data source is analysed by using a different analytical tool (i.e. thematic analysis) and a different focus (teaching practices).

In this chapter, findings from this analysis are integrated with findings derived from other sources of data (i.e. teacher interviews and student questionnaires). In order to contextualise discourse instances, classroom activities were sequentially ordered and represented in timelines. One timeline was produced for each of the 34 lesson periods examined in this study. The whole set of timelines is reported in Appendix D.

Activities timelines provide information on the kinds of activities and topics the students were engaged in and on the adopted discourse formats (e.i. triadic dialogues, monologues, peer to peer talks, and students' questioning dialogue). These timelines proved to be a useful reference tool throughout the whole analysis process for contextualizing outcomes. In addition, they revealed that the investigated classes were mostly a mix of whole-classroom dialogues led by the teacher—interspersed with usually short teacher monologues—and writing activities conducted in pairs or little groups and characterized by peer talk. Overall, the lessons were an alternating of recapping, explaining, discussing, seat work, checking previous seat work or homework. In terms of types of interactions, interactive forms of talk prevailed over monologic ones. In particular, only short forms of monologues were observed (i.e. longer than 2 minutes, but always shorter than five minutes) and were exclusively conducted by the teacher. However, the triadic dialogue (Lemke, 1990) was the most common form of interaction within whole-class dialogues (see Appendix D for details). This confirms the often reported pervasiveness of triadic dialogue, meaning the three-part initiation-response-evaluation (IRE) or initiation-response-feedback (IRF) discourse pattern (e.g. in Lemke, 1990; Wells, 1993). In this study, it is acknowledged that the triadic dialogue can be quite productive in terms of conceptual understanding and science language development when a CLIL approach is adopted (cf. Wells, 1993). Further details about how the triadic dialogue promotes science learning are presented in the following sections.

5.4.1 Interactions Analysis of Classroom Discourse

Transcripts complemented with field observations are analysed using a mixed methods approach to discourse analysis (Mercer, 2004, 2010). Contextually, data are also discussed in relation to relevant literature. The aim of this analysis is to identify how discourse practices support opportunities for learning science. In this section, a brief explanation of the principles that guided the analysis and of how data were methodologically analysed is provided.

Transcripts were coded mainly on utterance level within the following three components of classroom interaction: (1) teachers' questions and feedbacks (2) students' answer, and (3) students' questions. Teachers' questions are examined in relation to the answers provided by the students. Students' answers are investigated in terms of the type of knowledge they evoke and in relation to the verbal production they elicit. The analysis combines quantitative with qualitative elements. The quantitative aspect is represented by the frequency of the interaction moves both across the whole data set and across case studies. The qualitative element is represented by a discourse analysis of the observational data (see Mercer, 2010). This includes a selection of illustrative extracts of transcribed talk that are examined and discussed in relation to research questions and existing literature. Furthermore, findings from classroom transcripts are integrated with findings from other research components (teachers' interviews and student questionnaires) and interpreted as a whole.

The analysis is guided by four factors that are considered diagnostic for detecting conceptual understanding and science language development within classroom interactions, namely (a) students' cognitive engagements (b) verbal production about science, (c) sensemaking, and (d) access to science knowledge, as outlined in Figure 5.2. *Cognitive engagement* refers to the level of conceptual thinking that students use for building science knowledge, as theorized by Anderson and Krathwohl (2001) and used in science education, for instance, by Smart and Marshall (2013). *Verbal production* refers to the students' production of spoken language used for participating in classroom discourse. This factor has been chosen as determinant for defining opportunities for learning science not only because this study is situated in CLIL classrooms, but also because this study is theoretically framed within a communicational approach to cognition (Sfard, 2008), that values communication and participation as instrumental for thinking and learning. The concept of *sensemaking* is explained in section 3.6.3. Giving *access to science knowledge* means here addressing students' language demands and helping students to develop ways of expressing themselves *scientifically*. Giving *access to science knowledge* is a CLIL-specific factor and it draws upon studies on science education with multilingual students (e.g. Seah and Silver, 2018). The mentioned factors resonate with how opportunities for learning science have been conceptualized in this study (as explained in section 3.7.10).

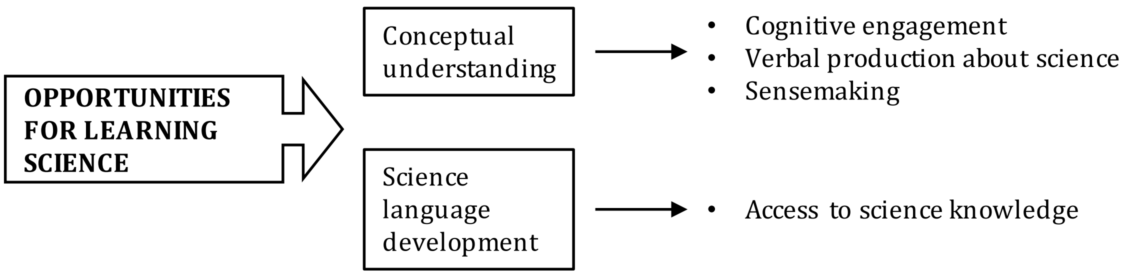

Figure 5.2 Factors that guided the interaction analysis of classroom discourse.

5.5 LOT Questions

Question asking is a common activity in the CLIL science classroom. Sequences of questions and answers were observed to be the most recurrent type of discourse teachers and students were engaged with and the most common activity throughout the majority of the 34 class periods examined (see Appendix D). Teacher's questions are classified according to the cognitive level required for answering them and to their pedagogic function. The general assumption is that different kinds of questions can stimulate the mind differently. In this study, teachers' questions were grouped into three broad categories: (1) Lower-Order Thinking (LOT) questions, (2) Higher-Order Thinking (HOT) questions, and (3) Language related questions (LQ).

I refer in this study to Higher-Order Thinking (HOT) skills in its widest sense, which encompasses issues such as the use of reasoning, critical thinking, and metacognition abilities (Schraw, McCrudden, Lehman and Hoffman, 2011). Lower-Order Thinking (LOT) skills refer to basic skills such as recalling information, describing, recognising and retrieving knowledge (Resnick, 1987). Table 5.2 shows the distribution of these questions' types across case studies. Differences across case studies must be interpreted cautiously as the number of recorded lessons, lesson topics and classroom activities were not homogenous across case studies.

Table 5.2 Frequency of teacher questions (n = 372) by category across case studies. The numbers in the table cells refer to how many times a particular category of question was coded.

QUESTION CATEGORY	CODES	CS1	CS2	CS3	Total	%
LOT Q (Lower Order Thinking) Questions	Recall Questions	61	14	27	102	27%
	Recognising and Describing	23	15	23	61	16%
	Guess What Teacher Thinks (GWTT)	0	0	27	27	7%
	Prior knowledge questions	1	2	26	29	8%
					186	**58%**
HOT Q (Higher Order Thinking) Questions	HOT Questions	45	35	10	**100**	**26%**
LQ (Language-related Questions)	Parlance Questions	18	5	22	45	12%
	Checking for lexical understanding	8	6	4	18	5%
					59	**18%**

The majority (58%) of questions teachers asked for building science were LOT questions, meaning questions that require a low level of cognitive engagement to answer them (cf. Chin, 2004). They were ubiquitous across the case studies and served many purposes such as recalling information, recognising and describing content materials, and gauging existing knowledge. Figure 5.3 graphically summarises this information.

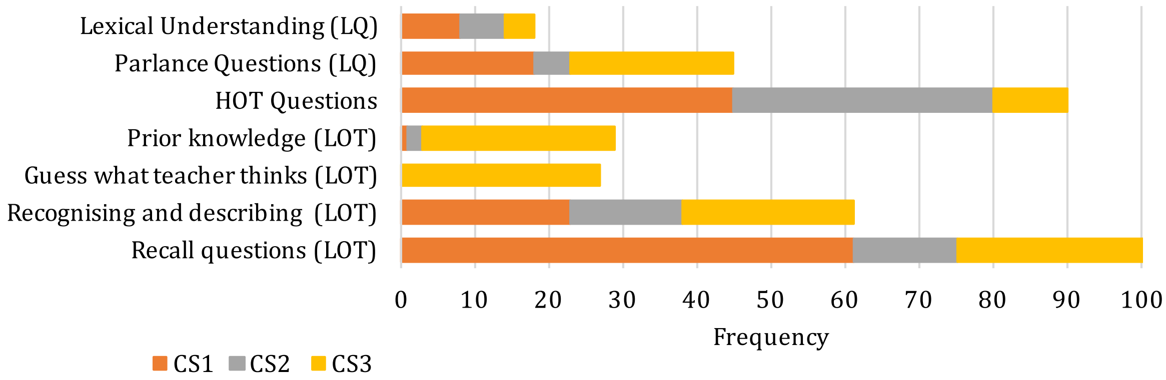

Figure 5.3 Frequencies of categories of questions across case studies

Teacher's questions were cross-checked with the cognitive level of student's answers. Students' answers were analysed in terms of cognitive engagement using the coding scheme proposed by Shavelson *et al.* (2003). This framework captures evidence of the use of four types of knowledge: *declarative* (knowing that), *procedural* (knowing how), *schematic* (knowing why), and *strategic* (knowing when, when how a certain knowledge applies to a new situation). These codes were designed to describe what type of knowledge is used by a student for replying to a teacher's question. In the data from this study, no one case of procedural knowledge was identified. Table 5.3 investigates the relationship between the types of questions asked by teachers and the level of knowledge evoked in students' answers.

Table 5.3 Matrix that combines types of teacher questions with type of knowledge evoked in student answers (n= 302). In the intercepting cells, frequencies of occurrence are reported.

	STUDENT ANSWERS		
CODES:	**Declarative knowledge**	**Schematic knowledge**	**Strategic knowledge**
LOT Questions (LOT Q):			
Recall questions	91	6	0
Recognising and Describing	41	7	0
'Guess What I'm thinking'	19	0	0
Prior knowledge questions	12	0	0
HOT Questions (HOT Q)	8	59	5
Language related questions (LQ):			
Parlance Questions	14	0	0
Total:	**74%**	**24%**	**2%**

The same relationship is graphically represented by Figure 5.4. Overall. it can be observed that, generally, LOT questions score low on cognitive engagement, as they nearly always evoke declarative knowledge (cf. Ernst-Slavit and Pratt, 2017; Smart and Marshall, 2013).

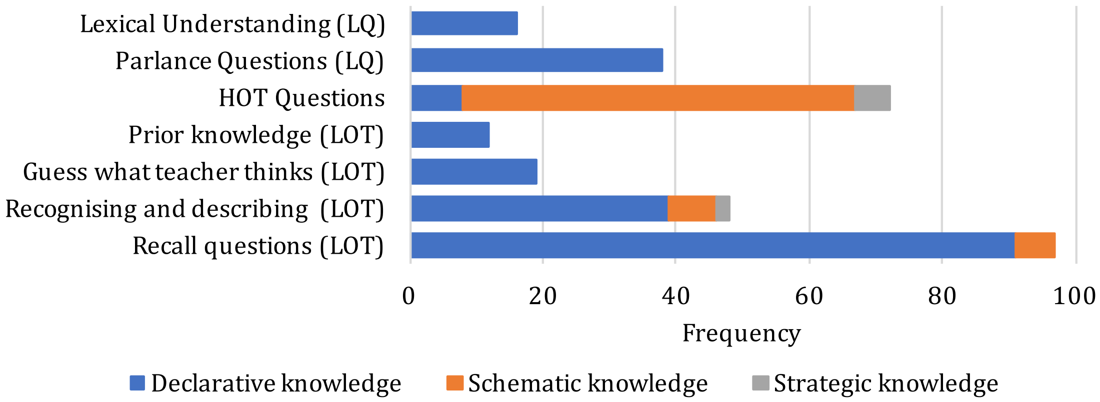

Figure 5.4 Types of teacher questions by type of knowledge evoked in students' answers (n = 302).

5.5.1 Recalling, Recognizing, Describing and Making Connections

In this study, the most recurrent LOT questions were *recall questions* (see Table 5.2 and Figure 5.3). Recall questions were used to check retention, to recall previously stated information, or to go over previous lessons for connecting them to the current discourse. Apart from this type of questions, LOT questions were also asked to recognise parts and to describe objects and processes. In this study, these were coded as *recognising and describing* and refer to thinking skills that belong to the lowest cognitive level described by Anderson and Krathwohl (2001). Sometimes, teachers feel it is important to support the introduction of a new topic by linking it to an already existing reservoir of knowledge, i.e. by activating students' prior knowledge, and thus by forging connections between old and new knowledge. These questions have been called *prior knowledge questions*. Although they only evoke low cognitive engagement, prior knowledge questions help learners make sense of the material presented (Ausubel, 1961). By recognising some connection between existing—or prior—knowledge and the new material that is being taught, the learning process is facilitated as it becomes more meaningful (Marzano, Pickering and Pollock, 2001; Taber, 2001) and new material is more easily memorized (Brewer and Treyens, 1981). In addition, prior knowledge questions help the teacher gauge what the students already know or think to know. In this study, prior knowledge questions were occasional and confined to when new material was introduced.

Overall, most LOT questions evoke declarative knowledge by *activating or reactivating* knowledge structures without structurally changing them (Heine, 2010). This process stands in contrast to *restructuring* or *constructing new* knowledge structures (von Aufschnaiter and von Aufschnaiter, 2003), which are both commonly referred to as *learning* and are promoted by HOT questions (from section 5.6). However, a finer-grained analysis of the use of these questions reveal that they have some learning potential, which is discussed later, from section 5.5.3 to 5.5.5.

5.5.2 Guess What Teacher Thinks!

A last type of LOT questions was found in the data set. These were labelled as *Guess What Teacher Thinks*, or *GWTT questions*. Basically, students are expected to guess what the teacher has in his/her mind (Young, 1992). The teacher gets the students to identify the correct answer, usually through a process of recalling knowledge that should already belong to the students. Basically, students have to think what the teacher is getting at and join in. Young (1992, p. 102) notes that this approach to questioning is more an "invitation for conformity […] rather than a provocation to the exploration of a question" and that this pattern of questioning has no educational justification, even though it is very common.

In this study, this category of questions was exclusively found in CS3, the case study where James teaches (see Table 5.2). All James' classes had at least a couple of examples of this category of questions, often more. Sometimes James used GWTT questions more as a rhetorical device rather than a pedagogical tool. The data found in the transcripts of James' classes confirm Young's claim that these questions rarely generate real thinking and that the clues that the teachers give are so many and so revealing that teachers come close to answering their own questions. Extract 5.1 provides an example of these questions.

Extract 5.1

TEACHER: […] Now, if I say digestive system,
what's the first thing you think up?
S: Liver?
Ss: [laugher]

[CS3-11A-1a, lines 36-39]

These type of questions always evoke declarative knowledge, which confirms Young's claim that these recitative questions do not add much value to conceptual understanding (Young, 1992). In addition, the GWTT questions found in this study were always answered at a one-word-level and very often chorally. Choral answers keep students engaged and may actually raise the tension as students do not take responsibility for their own personal answers. However, they also hinder the opportunity to learn science dialogically, as it is the teacher that dominates the dialogue. This situation is well depicted by Extract 5.2.

Extract 5.2

TEACHER: […]Because when Lorenzo reached
a certain point he was no longer able to...
Ss: Swallow. [choral answer]
TEACHER: Swallow, which means you're no longer able
to...
Ss: Eat. [choral answer]
TEACHER: Eat...or drink.

[CS3-11A-1b, lines 124-130]

These findings resonate with what Hajer (2000, p. 282) found about multilingual classrooms in the Netherlands, where she observed a connection between low demands on students' verbal production and "skeletonizing content." This aspect brings the argument to the next issue, i.e. the verbal production triggered by teacher's questions in students' answers.

5.5.3 LOT Questions and Verbal Production

Depending on what the teacher is asking to recall—ranging from a single to word to a complex mechanism—students may produce either very short or extended answers. In particular, two categories of students' answers were considered:

a) *One-word answers* or very brief expressions (word-level answers)

b) *Longer-than-a-word* answers (not word-level answers)

In this study, verbal production was identified as one of the key factors (together with cognitive engagement, sensemaking and access to science) that effect opportunities for learning science (as explained in section 5.4.1). The verbal production of students' answers was analysed across case studies and in relation to the types of questions asked. Results are reported in Table 5.4, which shows how short and long answers were distributed across case studies and in the whole data set. It is apparent how figures that represent occurrences of short answers dominate when LOT questions and language-related questions are asked (with the exception of 'checking for lexical understanding' questions). When HOT questions are asked, this pattern is inverted.

Table 5.4 Frequencies of short and extended answers (n = 322), by question type and across case studies. The first number in every cell represents the count of short answers (one-word) and the second number the count of long answers (non one-word).

Questions (codes)	CS1	CS2	CS3	Total
LOT (Lower Order Thinking) Questions				
Recall Questions	10 -- 51	6 -- 8	26 -- 1	42 -- 60
Recognising and Describing	5 -- 18	1 -- 14	22 -- 1	28 -- 33
Guess What Teacher Thinks	0 -- 0	0 -- 0	27 -- 0	27 -- 0
Prior knowledge questions	1 -- 0	0 -- 2	24 -- 2	25 -- 4
				122 -- 97
HOT (Higher Order Thinking) Questions	0 -- 45	0 -- 35	3 -- 7	**3 -- 87**
Language-related Questions				
Parlance Questions	12 -- 6	5 -- 0	22 -- 0	39 -- 6
Checking for lexical understanding	3 -- 5	5 -- 1	4 -- 0	12 -- 6
				51 -- 8
Gran total				**164 -- 158**

Figure 5.5 summarizes how short (one word) and long (longer than one word) answers were distributed in the whole data set. Overall, GWTT questions always evoked one-word answers or even no words at all (when the teacher answers themselves). In other words, the verbal production triggered by GWTT questions is very low.

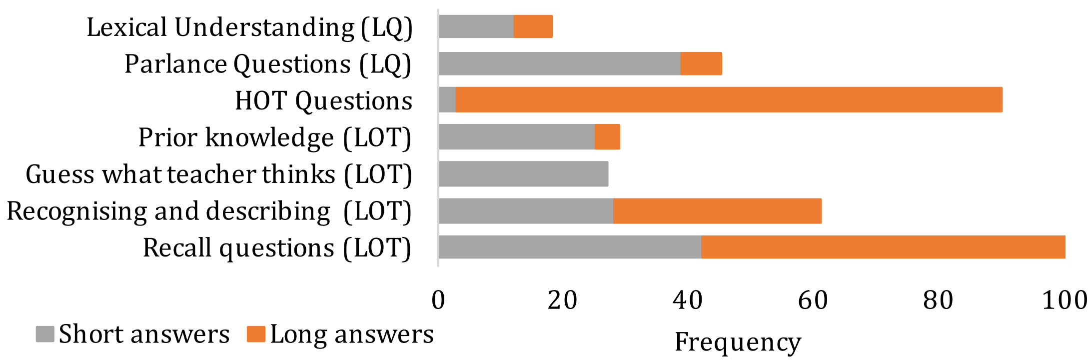

Figure 5.5 Short (word-level) and long (more than word-level) answers by question type across the whole data set.

To sum up, GWTT questions (only present in CS3) trigger both low-level cognitive engagement *and* low language production. By contrast, other low order thinking

(LOT) questions sometimes trigger long answers or even sensemaking. This possibility is explored in the next section where *recall questions* are analysed.

5.5.4 LOT Questions and Sensemaking

It has already been explained that LOT questions mostly trigger declarative knowledge. Declarative knowledge is the knowledge considered as a *body of facts* or the *knowing that* (Ryle, 2009). In science education, declarative knowledge entails descriptions of events, scientific terms, definitions, facts, or statements and Li, Ruiz-Primo and Shavelson (2006, p. 303) suggest that this type of knowledge only lead to "rote-learning". By contrast, the findings from this study suggest a different and more complex reality. The next three extracts show this point. In Extract 5.3 the teacher is asking two LOT questions of the *recall* type.

Extract 5.3

463. MAIA: Ehm...what's the difference between an allele... and a
464. (2.0) an...antigen?
[…]
469. TEACHER: […]Now, is there someone who
470. is willing to explain to Maia the difference
471. between an allele and an antigen? (1.0) Markus.
472. MARKUS: Uhm…alleles are the alternative forms of a gene.
473. TEACHER: Good, you remember this very well and where
474. are they (2.0) where can you find them, the alleles, in the
475. cells?
476. MARKUS: Uhm, in... in the nucleus (1.0). In the DNA?

[CS2-10A-2b, lines 463-476]

In this excerpt, Markus defines a scientific term as it appears in the textbook. Solicited by the teacher *recall question* he answers it. In both Markus' answers, the cognitive demand actually resonates with what Li *et al.* (2006, p. 303) describe as the "rote-learning of declarative knowledge". Markus, however, only answered to half the question. A little later, in the dialogue, (Extract 5.4), the teacher asks Alvin:

Extract 5.4

499. TEACHER: […] Now, what's an antigen of the ABO system and
500. where are these antigens in your body? (4.0) Alvin.
501. ALVIN: You said they are...sugars?
502. TEACHER: Mm-hm, and where are they?
503. ALVIN: In the red blood cells.
504. TEACHER: *On* the red blood cells, on the red blood cells
505. surface.

[CS2-10A-2b, lines 499-505]

In this extract, Alvin makes use of declarative knowledge, again, answering two recall questions. It is apparent here that the student is merely remembering because of his use of metadiscourse "you said" (line 501), which sounds a bit at odds within the science classroom. At lines 504 and 505, the teacher follows up on Alvin statements by recasting it. Some lines below (Extract 5.5) in the same dialogue, the teacher goes back to Maia's original question asked in Extract 5.3.

Extract 5.5

514. TEACHER: […]Now, Maia, I'm asking you now. What's the
515. difference between an allele and an antigen when we
516. refer to the red blood groups. (2.0)
517. MAIA: Okay...the alleles are the...information…on the DNA.
518. They...decide what blood group you are. (2.0) The antigens
519. are the (2.0) product of the alleles. They are...on the red
520. blood cells and they tell you...what's your blood group.

[CS2-10A-2b, lines 514-520]

Something has happened between line 463 and 517, because this time Maia is able to answer her own question (Extract 5.5). Even though Maia is basically making use of declarative knowledge, her answer is cognitively rather complex and linguistically rich. Maia sums up all what has been said by Markus, Alvin and the teacher by using her own words. For instance, instead of using the academic term *gene* she says "information on the DNA". Maia is making use of what Lemke (1990) called thematic items which she connects with the right semantic relationships. In other words, Maia is learning science. This is an example of how students make sense in real time, rather than reconstructing from previous thinking. Learning science is in this case collaboratively accomplished through the orchestrated interactions between students and teacher. Here "discourse does not only express meaning. Discourse creates meaning" (Mohan and van Naerssen, 1997, p. 2). The *something* that happened between line 463 and line 517 is indeed *sensemaking*.

The purpose of showing this sequence of extracts (Extract 5.3, Extract 5.4 and Extract 5.5) is that, even if it is true that asking LOT questions and using declarative knowledge is not strictly cognitively demanding, their use in the CLIL classroom discourse does not necessarily lead to "rote-learning", as Li *et al.* (2006) would suggest. The results of this study show that "declarative knowledge also falls under the rubric of science education" (Good, Herron, Lawson and Renner, 1985, p. 140). Extract 5.6 provides another example of how recall questions and declarative knowledge can indeed be rather challenging when students are asked to define an abstract concept using their own words.

Extract 5.6

> TEACHER: […]You
> remember what validity means? (1.0) Niko?
> NIKO: So, how close... (1.0) how close are our results...
> TEACHER: That's more reliability, actually…
> NIKO: Oh, yeah, yeah, so...validity (1.0) uhm, validity
> is something...
> TEACHER: Mmm (2.0)
> NIKO: It's the process to the...the answer, uhm...the...
> TEACHER: I know it's in your head and you're trying to
> verbalize it. And it's not coming out, but Maia [who's
> raising her hand] is going to help you.
> JOHANNA: Isn't it the—[unintelligible]?
> TEACHER: Pardon?
> JOHANNA: Isn't it how... how we use the results...how valid
> they are in general in the whole experiment?
> TEACHER: Yeah, I like that. That's exactly what validity
> is. How far-reaching your results are and how much you can
> trust your results and base conclusions on them. Absolutely.
> That's validity!

[CS1-11-1a, lines 149-169]

In Extract 5.6, students are asked to "remember what validity means". The concept had been learnt before and the students have now difficulties in remembering it. Therefore, they have to make up a definition using their own words. After the (erroneous) contribution of Niko, Johanna cautiously provides an answer with some hesitation (line 165). She uses declarative knowledge, as she is answering a what-is-that type of question. However, answering requires some effort, as Johanna has to recollect the vague memory of an abstract idea, to amend it with the hints provided by the teacher and by Nico and, finally, to verbally translate her thoughts into words. Johanna is actually doing what Odden and Russ call *sensemaking,* which the authors define "as a dynamic process of building an explanation in order to resolve a gap or inconsistency in knowledge" (Odden and Russ, 2019, p. 199). Johanna is *figuring out* what validity is and she is doing it by *using her own words*. As noted in Chapter 3, section 3.6.3, literature on sensemaking highlights how building an explanation through your own words (or language) is a key part of the sensemaking process, meaning that the explanation you are building is meaningful to you (e.g. Hutchison and Hammer, 2010; Warren *et al.*, 2001).

5.5.5 The Potential of LOT Questions

As evidenced by the previous examples of classroom speech, the combination of LOT questions, declarative knowledge and orchestrated dialogue (i.e. strategic placement of questions) contributes to science learning in a CLIL upper secondary context. Overall, these extracts have shown that it is how LOT questions and students' declarative knowledge are contextualized and embedded in the classroom talk that makes the difference in terms of opportunities for learning. There are two important factors that make the difference between low-cognitive questions that *do not* contribute to science learning and low-cognitive questions that *lead* to sensemaking. These are (1) students' verbal production and (2) the dialogic process questions are immersed in, meaning the strategic use of questions mediated by the teacher. *Recalling* and *recognising and describing* questions can lead to invaluable processes of sensemaking that nurture science learning unless the students provide one-word answers. It is indeed *through* the dialogue built *on* everybody's language that sensemaking is collectively constructed and opportunities for learning science emerge. This finding is summarized in Figure 5.6 and contributes to answering RQ1.

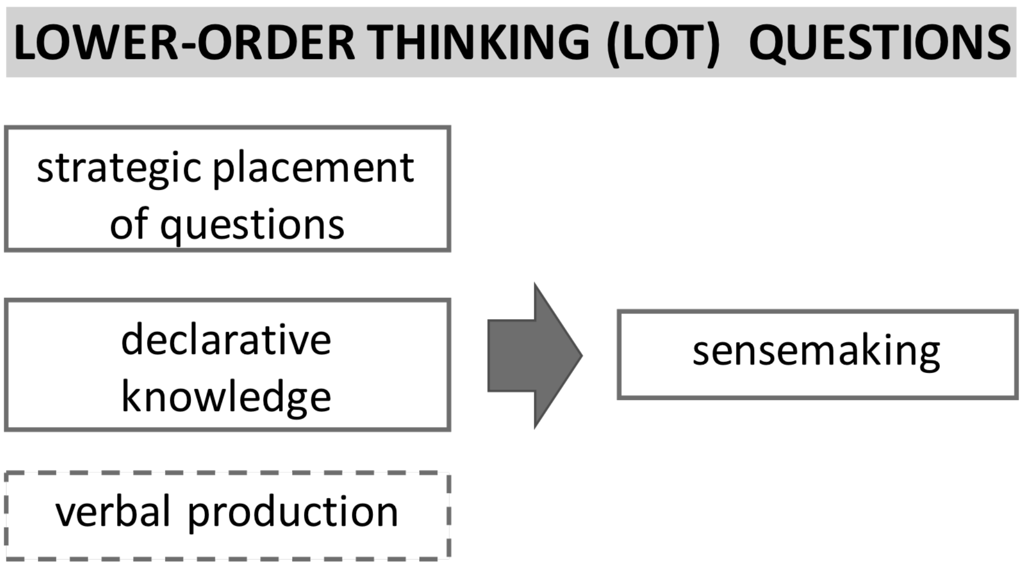

Figure 5.6 Model of characteristics of LOT questioning that promote opportunities for learning science. Sensemaking cannot take place if the other three factors are not present. Verbal production is the most critical aspect of these kind of questions.

This is the first study that empirically analyses teachers' questioning in CLIL classrooms for the purpose of science learning. In upper secondary science classrooms, as the ones investigated in this study, it is expected that effective learning demands high cognitive engagement, which mirrors the students' cognitive level. This type of cognitive engagement is present both in CS1 and CS2, but not in CS3, where James decides to deal with the students' linguistic barriers by letting students answer chorally and by limiting the questioning to what does not elicit verbal production. This approach lowers the linguistic demand on the students. However, by doing this James also lowers the cognitive engagement. What James faces is a typical situation of many CLIL classroom: a mismatch between students' cognitive level and students' linguistic level. For instance, in a study on Physical Education taught in Irish through a CLIL approach, Ceallaigh, Mhurchú and Chróinín (2017, p. 77) found that "[l]ess cognitively demanding PE content was taught as a consequence of the lack of students' receptive and productive skills in Irish." Coyle (2007, p. 555) argues that "[p]erhaps this is one of the major challenges for CLIL". For overcoming this *language-level/cognitive-level* mismatch Coyle (2007) recommends to ensure a cognitive progression by gradually working from lower towards higher linguistic demands, which in CLIL settings includes making cognitively demanding task linguistically accessible. Some solutions and considerations about how this was achieved in the science CLIL classrooms of this study is presented and discussed in the next sections.

5.6 HOT Questions, the Teachers' Pets

In this study, HOT questions—or Higher Order Thinking questions—are those questions that ask students to use higher order thinking skills in order to respond, such as reasoning skills, argumentation, use of evidence, critical thinking, and metacognition abilities (Schraw *et al.*, 2011). In a science classroom, these questions are meant to guide and scaffold the building of conceptual understanding and to check the students' understanding (Kawalkar and Vijapurkar, 2013). In this study, HOT questions were approximately half as frequent as LOT questions (see Table 5.2). The relatively high frequency of HOT questions in these data is very much at odds with what Dalton-Puffer (2007, p. 125) found in Austrian secondary CLIL (not specifically science) classrooms. In Dalton-Puffer's study, most of teachers' questions are factual: "[t]he bread and butter of Austrian CLIL classrooms is obviously facts, facts, and facts". The discrepancies between findings may be explained by the different subject matters involved (science versus a wide range of different subjects) and the school level (upper secondary versus a wider range of ages). These discrepancies also indicate that CLIL research, so far, has not produced research findings that are informative to science learning practice.

In the science classrooms of this study, HOT questions appear to be the highlight of the classroom questioning and science teachers seem very partial to them. The exchange in Extract 5.7 provides an example of this.

Extract 5.7

1. TEACHER: I need one of you to go over to the experiment
2. we did last time. What did you do? Sebastian.
3. SEBASTIAN: We cut little cubes of potatoes, uhm…and placed
4. them in small cylinders, each with 5 millilitres and then we
5. weighted them. And then we found each weight of the
6. cylinders–
7. TEACHER: Mass
8. SEBASTIAN: Mass. We found the mass...of each the cylinder.
9. And…uhm and we had five cylinders for one...uhm, for
10. one, uhm...
11. TEACHER: So, what were you actually investigating?
12. SEBASTIAN: Uhm...
13. TEACHER: Apart from what you had, and they had...what
14. was the point?

[CS1-11-1, lines 1-14]

In Extract 5.7, Alexandra, the CS1 teacher, asks Sebastian to describe a recent experiment. At the end of the exchange, it is palpable the growing irritation of the teacher at the wordily description provided by Sebastian. Alexandra asks “what were you actually investigating?” and “what was the point?” (lines 11-14), meaning that she is more interested in the reasoning that underpins the lab experience than in mere descriptions. This is something that deeply differentiates any science classroom from a language classroom. In the latter, a wordily description may have a place and a value of its own. Science education, however, has other goals and even seemingly LOT questions, such as “What did you do?” (line 2) may end up requiring HOT answers.

Sometimes HOT questions are *disguised* as cognitively less demanding ones, as in Extract 5.8, where Emma, CS2 teacher, is asking to *describe* a diagram.

Extract 5.8

TEACHER: Please, describe the picture and explain to me what it means [showing a picture with the overhead projector of the electromagnetic spectrum that highlights the visible part of the spectrum]. (9.0) Milo, what's that? [Pointing at the picture]

[CS2-11-1, lines 1-4]

It is not a mere description that Emma is asking. What she is aiming for is to get the meaning of the diagram: “what does it mean?”. In order to answer this question, her students have to be able to analyse the parts of the diagram (a spectrum of the visible light), understand the measure units on it, compare wavelengths and apply their prior knowledge to make sense of the diagram as a whole. HOT questions are indeed cognitively demanding (Chapin and Anderson, 2003; Chin, 2006). Emma realizes this and allows quite a long wait time (9 seconds) before asking Milo. The cognitive demand of these questions on students is analysed and discussed in the next section.

5.6.1 HOT Questions and Cognitive Engagement

In science classrooms, HOT questions hold a privileged position. It is reported that they foster deeper conceptual thinking (Chin, 2004; Yip, 2004). Therefore, the presence of HOT questions is an indication of opportunities for learning science. As evidenced by Table 5.3 and Figure 5.4, in this study, HOT questions were observed to mostly elicit schematic and, occasionally, strategic knowledge. Wells (2010, p. 201) describes schematic knowledge in science education as "a student's ability to explain and predict natural phenomena, and to use reasoning in their evaluation of scientific claims regarding those phenomena". Very briefly, schematic knowledge means *knowing why* (Li *et al.*, 2006). Extract 5.9 provides an example of schematic knowledge, where Silvia is asked to explain the reason of her statement.

Extract 5.9

SILVIA: […] So, I can't be sure whether I'm heterozygous or homozygous for those traits.
TEACHER: Can you explain to me please why you can't know that for sure?
SILVIA: Uhm, both my parents and me show the dominant characters. So, I do not know whether the dominant allele comes twice or it just...masks the recessive allele. Both my parents have these dominant traits, they have brown eyes, for example. And I don't know whether or not they have the recessive gene as well.

[CS2-10A, lines 172-186]

Silvia's explanation is relatively long and articulated and the explanatory models she applies can only be accessed through organized pre-existing bodies of knowledge (Furtak and Ruiz-Primo, 2008).

Strategic knowledge is considered to be the highest order learning level among the cognitive demands (Wells, 2010). This form of knowledge relies on a student's ability to transfer knowledge in solving new problems. It has been labelled as the "knowing when, where, and how to apply knowledge" (Li *et al.*, 2006, p. 292). It often entails the ability to integrate other types of knowledge in an efficient manner, as evidenced by Extract 5.10. In this extract, Milo is using strategic knowledge to provide a solution to the problem posed by the teacher.

Extract 5.10

TEACHER: […] how could I discover the
genotype of my dog without any DNA analysis? (3.0)
Please, discuss this in pairs for a minute.
[…]
What do you suggest here? Milo?
MILO: We think we could wait to see the puppies of the dog.
TEACHER: And...
MILO: And...uhm…if at least one puppy is...yellow, then the
black father...or mother is small e and big E.

[CS2-10A-1, lines 215-224]

To solve the teacher's problem, Milo needs domain-specific strategies. In this case, this means possessing the knowledge of how genetic inheritance works, being able to represent the current problem with a Punnett square (a genetic tool for representing Mendelian inheritance) and being creative enough to plan a simple strategy. The teacher asks Milo to expand on his answer ("And…"), which forces him to make his reasoning visible to all and to use language to argument his point.

The analysis of the integration of HOT questions in classroom discourse bring us to the conclusion that HOT questions are a discourse practice that promotes and facilitates cognitive engagement. This finding contributes to answering research question RQ1. Indirectly, also the practices that scaffold HOT questions contribute to answering this research question. These are examined in the next section 5.6.2.

5.6.2 The Win-Win Case of HOT Questions

HOT questions can usually be answered only through extended answers, as a single word is hardly likely to answer any *why question*. Indeed, Figure 5.5 shows that HOT questions mostly triggered long answers. In this sense, HOT questions are a win-win: they are both cognitively engaging *and* linguistically productive. However, the need to provide articulated and more extended answers (as in Extract 5.9) raises the linguistic bar of the talk. As a result, in a CLIL science classroom, linguistic barriers can hinder the implementation of this category of questions. However, there are instructional tactics to minimize this effect. In this data set, the following scaffolding forms—some linguistic and some cognitive in nature—have been observed:

a) giving some time to discuss problems among peers before interacting with the whole class (as evidenced by Extract 5.10);

b) rephrasing the questions to make them clearer and to expose the students to the lexical repertoire they need for answering them;

c) increasing wait-time (Extract 5.8);

d) giving clues and cues to nudge students' thinking in the right direction;

e) inviting to use any language for answering;

f) using strategic placement of questions.

Some of these strategies are investigated in the next chapter, which focuses on teacher's practices. In this chapter, the last point (f) is further discussed here because of its relevance to classroom interactions, which are the focus of this chapter. Being cognitively engaging means that HOT questions are tough. The thinking process necessary to answer them may be complex, like a multi-step problem. As a consequence, science teachers need to be very strategic when asking HOT questions, as in Extract 5.11.

Extract 5.11

TEACHER: […] Why do we do that [disinfect wounds]?
S: To prevent infections.
TEACHER: Which means what?
S: Bacteria.
TEACHER: I actually have bacteria all over my skin. And so do you. But I do not pour any disinfecting solution all over myself, regularly I mean. Why am I supposed to disinfect a cut?
S: To prevent bacteria from…getting…entering the body.

[CS3-11A-1a, lines 137-145]

In this extract, James—CS3 teacher—orchestrates a questions' sequence that gradually guides students through the reasoning process. James is using his knowledge of the subject matter to formulate questions which guide the *methodology* of the students' thinking towards an answer which is based on reasoning, instead of giving the answer himself. As Ernst-Slavit and Pratt (2017) note, the skill of asking questions is more nuanced and complex than educators may realize. In addition, effectively asking questions is more far-reaching than it appears. In this regard, if we apply Bandura's socio cognitive theory of learning (Bandura, 1986) to questioning, it could be inferred that students also learn by observing and listening other peers successfully answering and reasoning. This has been confirmed by Chin (2007), who observed in regular science classrooms that effective teacher questioning also provides peer students with opportunities to vicariously learn from others' interventions. In L2 classrooms, it could be argued that students who successfully answer provide their peers with opportunities to also learn how to use science language. In this sense, a whole classroom can benefit from a verbally rich and stimulating learning environments (cf. Smart and Marshall, 2013).

5.6.3 HOT Questions and Sensemaking

By shifting the focus from the teacher to the students, it can be noticed that when students are asked a HOT question, they either already know the answer, which they provide through an *explanation* (as in Extract 5.9 and Extract 5.10) or they do not already know the answer and have to *figure it out*. In the latter case, students are engaged in the process of *sensemaking*, which entails "forging new connections between existing knowledge, whereas explanations can be generated without the need for any new knowledge or connection" (Odden and Russ, 2019, p. 198). In Extract 5.12, students are trying to *figure out* how the antibiotic resistance process works.

Extract 5.12

TEACHER: […]why is the bacterium that mutates so so so successful? (2.0) So, why is the antibiotic resistance becoming so common and widespread? What do you think? You have to think a little. (2.0) Amelie?
AMELIE: I think, every time a bacterium mutates you need another, a new antibiotic and so it's pretty hard to...uhm, to...
TEACHER: Mm-hm, to catch up with their changes. Yeah, but that's a sort of long-time effect. […]
Aber ich frage noch mal, warum sind die Bakterien so erfolgreich geworden? <I'll repeat the question. Why have bacteria become so successful?>
Think what would have happened. (2.0) Sophie?
SOPHIE: Maybe...when the infected people—uhm the doctors... uhm, don't know how they should fight bacteria because uhm, they...uhm—the most successful medicines don't work anymore and...uhm...
TEACHER: It's even before that. You guys are thinking too far ahead. So, imagine now you're taking an antibiotic and there is one bacterial cell that has a mutation which means it can survive. So why is this one cell so successful? Think about what we know about bacteria. Ida?
IDA: The mutated cell can divide now... freely.

[CS1-10A-2, lines 106-128]

The process of sensemaking is here both cognitively and socially constructed. In order to answer, Ida needs to connect some old knowledge about how bacteria reproduce, about what a mutation is, about ecology and competition. In order to provide the correct answer Ida also capitalizes on the (wrong) contributions of Amelie and Sophie and the cues provided by the teacher.

So far, it may be taken as an evidence that HOT questions nurture science learning both cognitively and dialogically. They are nearly always cognitively engaging as they mostly trigger schematic and (occasionally) strategic knowledge. They are verbally productive, as they nearly always produce longer-than-a-word answers. When they are oriented to *figure things out* they also produce sensemaking. These findings are summarized by Figure 5.7.

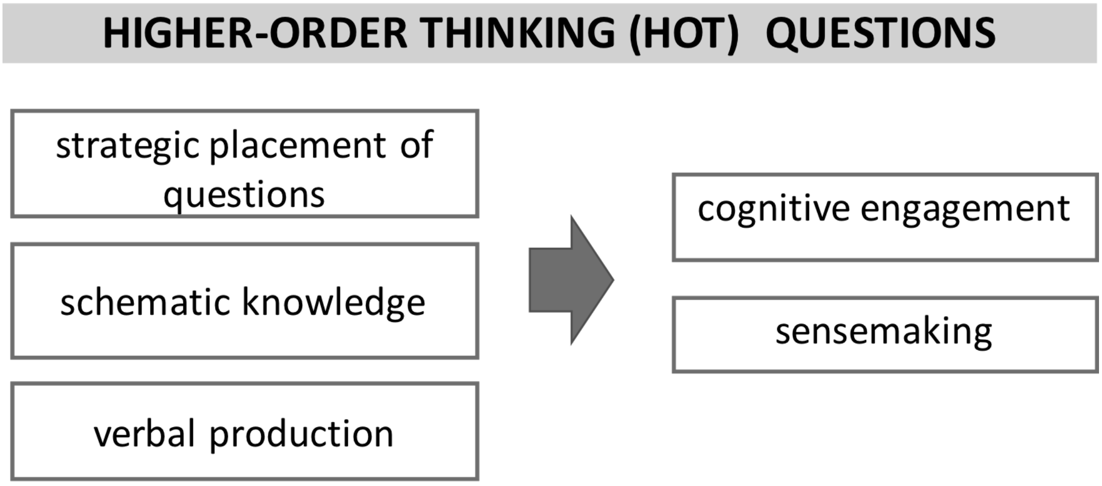

Figure 5.7 Model of characteristics of HOT questioning that promote opportunities for learning science in CLIL classrooms.

5.7 Strategically Building on Students Answers

What so far has been generally called *strategic placement of questions* is further investigated here. Even though questions alone do indeed set the bar for cognitive engagement, how questions are interwoven in the communication is cognitively relevant too. In particular, the contingency of questions on previous student utterances has been recognised to have the potential to promote "both structurally elaborate and accretive student talk" (Boyd and Rubin, 2006, p. 141). As talk mediates learning (Vygotsky, 1986), contingently responsive teacher behaviours that promote classroom talk have also the potential to create opportunity to learn. In education, the particular form of contingent disciplined, systematic and deep questioning used by the teacher to prompt and guide students' thinking is sometimes called Socratic questioning (Chin, 2007; DePierro *et al.*, 2003; Elder and Paul, 1998). This form of questioning promotes deep-thinking, as it helps learners see connections and use prior knowledge effectively (Paul and Elder, 2007). Socratic questioning is based on sequences of questions that aim to extract information within the students instead of telling information via lecturing. Even if they have not been labelled as such, examples of Socratic questioning have already appeared in the extracts of the previous sections (e.g. Extract 5.9 and Extract 5.11) and they relate to both LOT and HOT questions.

Table 5.5 illustrates how frequent this type of questioning was across case studies.

Table 5.5 Frequency of Socratic questioning occurrences (n = 179) across case studies.

Socratic questioning	CS1	CS2	CS3	Total
Extending (What else?)	44	32	13	**89**
Probing (Why so?)	30	26	8	**64**
Constructive challenge	20	3	3	**26**

Overall, 56% of all teachers' questions for building science found in the data corpus are contingent questions framed within sequences of Socratic questioning (n=179), meaning that often questions are not isolated in the classroom talk, but they tend to come together and to build on one another and on the previous students' utterances. In this study, the framework used for analysing this aspect of the process of teacher's questioning is based on the work by Chin (2007), which discriminates between *extending, probing* and *constructive challenge* as forms of Socratic questioning.

5.7.1 Extending Questioning

Chin (2007, p. 824) describes *extending* questioning as the teacher's act of "pumping the student for more information during the question-answering process and putting the onus on the student to provide more information". Extract 5.13 provides a good example of this sort of *drilling* for more information.

Extract 5.13

TEACHER: Yes, and which cells are destroyed first?
ROSY: [hesitantly] The hair cells?
TEACHER: Yes, and where?
ROSY: [Whispering hesitantly] In the inner ear?
TEACHER: Yes, and where exactly? (3.0) Okay, you were correct, so far. It just wasn't detailed enough. Uhm, let me ask somebody else. Leon?

[CS2-10B-1, lines 237-244]

In this study, extending questions were enacted in different ways. Sometimes, students were encouraged to further articulate their thoughts. Other times, the teacher explicitly requested more details or higher specificity. The questioning strategy of extending mostly used either *recall* or *recognising and describing* questions (see Figure 5.8).

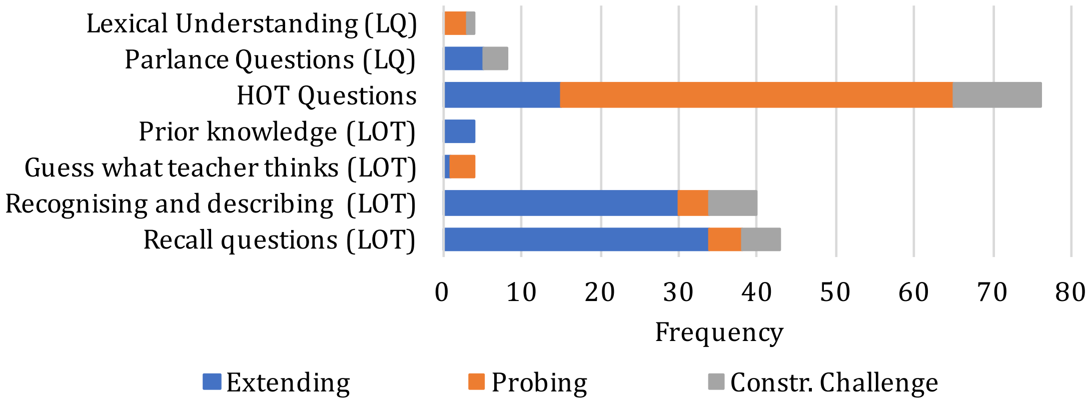

Figure 5.8 Socratic questioning events (n = 179) across case studies.

The previously quoted Extract 5.3 and Extract 5.4 are both examples of how the *extending* strategy works in *recall* type of questions. As *recall* and *describing* questions often produce declarative knowledge, also extending strategies generally evoke declarative knowledge. However, although requests for extending do not rank high in the scale of cognitive engagement, they can stimulate science language development, depending on how questions are asked. For instance, in Extract 5.13 students only provide one-word answers. However, in Extract 5.14, Sophie needs to produce more language for describing how the iris reflex works. In this case, extending strategies may be also elicited by brief affirmations (e.g. nodding, "Okay") or neutral feedbacks followed by silent expectation ("Uh-huh", "Mm-hmm").

Extract 5.14

TEACHER: [...]what's the effect
of the two muscles on the iris? They are directly attached to
the iris. (1.0) Sophie.
SOPHIE: Uhm... the circular muscles...
TEACHER: Circular muscles, right. Not to be confused
with the ciliary muscles.
SOPHIE: Uhm, the circular muscles and the... radial?
Radial muscles?
TEACHER: So, they work in opposite ways. Do you
remember how that works?
SOPHIE: So, uhm, when the iris closes, uhm... the pupil
gets smaller.
TEACHER: Mm-hm.
SOPHIE: And, uhm this is because the... circular muscles
contract?
TEACHER: Yeah, good! What else?
SOPHIE: And when the iris opens, because... it's dark...
uhm, the radial muscles contract and the pupil gets...

larger....
TEACHER: Yes, in dim light.
SOPHIE: And that's the iris reflex.

[CS1-10A-1, lines 62-82]

To conclude, *extending*, has been observed to promote science language development through verbal production. However, this questioning technique used alone neither support cognitive engagement nor sensemaking. On the other hand, when extending is combined with HOT questions things may change. This is exemplified (Extract 5.15) and discussed in the next section.

5.7.2 Probing Questioning

Probing questioning is another example of Socratic questioning. *Probing* means asking about the reasons of a statement or of a concept by asking questions such as Why?, How come?, So what? (Rappa and Tang, 2018). The main function of these questions is for the teacher to check how deep a conceptual understanding is. They follow a correct statement and investigate if the student's reasoning is solid and based on correct foundations. In this sense, probing questions are also diagnostic questions. Most of the HOT questions observed in this study (n = 77) were also probing questions (n = 55), meaning that the teachers asked most of the higher order thinking questions as part of contingent moves on students' utterances. Accordingly, these questions normally evoke the display of schematic knowledge and the production of longer-than-a-word answers. Often, probing questions are woven in IRF sequences of classroom talk together with extending questions. When strategically placed in dialogue, probing can also produce sensemaking. Extract 5.15 exemplifies how students make sense of the concept of antibiotic resistance. The sensemaking process is here promoted by probing questioning used in sequence with extending questions. As the extract is rather long, relevant utterances that exemplify teacher's probing questions have been underlined by the author to facilitate the reading process.

Extract 5.15

533. TEACHER: […] Why
534. are some bacteria becoming resistant? […] Any ideas? (2.0)
535. Anything becomes resistant...if given it enough time. Emily.
536. EMILY: Uhm, I think bacteria become resistant when you
537. take antibiotics for a long time but you never take the doses
538. higher...you take too low doses. Uhm, and bacteria... they
539. get used to it. So, they…Uhm…
540. TEACHER: Mmm, getting used to it is kind of a good way
541. of describing it. Does anyone have any idea what this

542. getting used to antibiotics might involve? (1.0) Because
543. how can something just get used to it? So, something's
544. underlying that, which is really important here.
545. EMILY: Maybe it's like evolution... they adapt to the
546. antibiotic so it's not harmful anymore.
547. TEACHER: Yeah, very much so. So, the term of evolution,
548. or evolving comes in here. Which means that they change.
549. Any idea about what changes about them? What can make
550. something change in an organism. Emily, what makes you
551. change? What makes people change from generation to
552. generation? (2.0) Never thought about it? It's gonna to be a
553. great topic next year. What can change in you? (1.0) Just
554. two people? Three people? Paula?
555. PAULA: Perhaps they make a stronger cell wall?
556. TEACHER: Yeah, that could change, but in order to do that
557. something else has to change, first. (1.0) What determines
558. everything about an organism? *Stoffwechsel, Ansicht*...
<metabolism, how they look like>
559. EMILY: The DNA?
560. TEACHER: The DNA, yeah, right. So, does anyone knows
561. what it is called when DNA changes? DNA is the... the
562. Hauptinformation. Wenn dies verändert, wie heißt das?
<the main information. What is it called when it changes?>
563. What do we call this…Leon?
564. LEON: *Eine Mutation* <a mutation>.

[CS1-10B-2a, lines 533-564]

In this extract, Alexandra—CS1 teacher— introduces a problem to which her students do not know the answer. In other words, her students have to *figure out* the solution. After a brief wait time, Alexandra gives the students a cue that encourages Emily to try to answer. Emily’s answer brings the talk close to the solution, but not there yet. Alexandra builds on Emily’s answer and asks another HOT question. So far, Alexandra has been using the strategy of *probing*. In her second answer, Emily gets even closer to the solution by suggesting the concept of evolution, but she remains too vague about it. Again, Alexandra builds on the student’s utterance. But this time, the teacher implements her Socratic questioning with an *extending* kind of questioning. First (lines 549 and 557), she asks two LOT questions of the *prior knowledge* type. At this point, Paula offers a potentially correct answer, but she is not able to exactly pin down the underlying principle the teacher is asking about. After that Alexandra furthers her *extending* questioning with a language-related question by asking “what is it called?” (line 561). All along the exchange, Alexandra provides cues. Finally, Emily answers correctly. Overall, it can also be observed that the individual students’ contributions are not overly long. It may be that the splitting of the thinking process into cognitively more manageable steps guided by teacher's questioning is mirrored by the splitting of the students' verbal production into more manageable chunks of speech, which may lessen the linguistic load on CLIL students. In this sense, Socratic questioning practices may not only promote but also facilitate science language production as they guide students to use only a small number of key science vocabulary words in context at a time.

As evidenced by the analysis of the questioning strategies in Extract 5.15, sensemaking can be supported by contingent questioning. In this case, HOT, LOT and language-related questions contingent on students' utterances are implemented and skilfully interwoven in the talk. As the process of sensemaking is supported by quite a long exchange with numerous more-than-a-word answers it also promotes a science language development. In addition, it could be seen that questions alone are not always enough to lead the students to answer them. Students also need to be nudged by cues, which the teacher provides. Briefly, probing, extending and giving cues provide cognitive scaffolding and enhance cognitive engagement. Furthermore, these practices provide both cognitive and linguistic scaffolding as they promote and facilitate verbal production. This finding aligns with what Alexander (2001) found in his international comparative study conducted in primary classrooms: even though the triadic dialogue is ubiquitous, it can be used in different ways. Alexander observed that when teachers frequently probe students' responses, both cognitive engagement and verbal production—with more formal use of academic discourse—benefit.

As a last remark, in Extract 5.1, it can also be noted that sensemaking is promoted by code-switching to L1. This aspect of the CLIL science classroom dialogue is further analysed in the next chapter, section 6.8.4.

To sum up, both contingent questioning and teacher's cueing can potentially facilitate sensemaking, science language production and cognitive engagement, within a CLIL upper secondary science context. This is dependent on how skilfully the sequencing of the appropriate questions is crafted. This result resonates with Boyd and Rubin's assertion that "it is not sufficient to look at the structure or type of question. One must inquire how the question functions within the stream of discourse" (Boyd and Rubin, 2006, p. 166). Overall, these data indicate that the triadic dialogue can indeed support high-level learning, which teachers can promote by structuring questions. These findings contribute to answering RQ1.

5.8 Questions for Promoting Access to Science

In CLIL classrooms, barriers to content access may be not only conceptual in nature but also linguistic (Kääntä and Kasper, 2018). In response to this fragility—which is specific of CLIL settings—teachers have been observed to engage in a third broad category of questions, labelled here as *language-related questions*. These questions shift the dialogue focus from content to linguistic aspects. In this study, language-related questions comprise two types of questions, coded as: (1) *parlance questions*, and (2) *checking for lexical understanding*. These questions signal that the teacher is focusing on the language of the discipline, either for promoting its use and development or for checking students' linguistic comprehension. In this data, language-related questions usually elicited answers with display of declarative knowledge (Figure 5.4), even though some sensemaking events occasionally emerged.

In particular, *parlance questions* are defined as questions that "prompt the use of genre specific ways of speaking the language of the discipline" (Ernst-Slavit and Mason, 2011, p. 4). In this study, these questions always refer to academic words. Their function is either to recall words that have been previously learnt or to activate or check some previous language-specific knowledge. Examples of these questions are: "Do you remember the posh word?" and "What do we call this?". In the examined data, parlance questions represent the 12% of all questions (see Table 5.2). Therefore, their presence may be defined as occasional, whereas in the linguistically diverse elementary classrooms investigated by Ernst-Slavit and Pratt (2017), these questions are among the most common. Parlance questions usually refer to academic language and reflect the teachers' belief that appropriately naming objects and concepts is important for the sake of science. This approach to science vocabulary offers students a better opportunity to get acquainted with a formal aspect of the discipline—i.e. the thematic terms—which are the objects on which the disciplinary understanding is build (Lemke, 1990). The previously analysed Extract 5.15 contains an example of parlance questions (line 561). It can be noted that the student's answer is made of a single word, which is how parlance questions are usually answered to. In addition, in this example, the answer is given in L1. In this study, parlance questions support access to the language of science but, for their very nature, do not support extended verbal production.

The *checking for lexical understanding* questions evoke both short and long answers, depending on how they are asked. Long answers have been observed when teachers ask for examples (as in Extract 5.16) or when they explicitly ask for the functional meaning of a term (Extract 5.17).

Extract 5.16

TEACHER: […]Now, the effects of exposure to loud noises are cumulative. What does it mean? (2.0) Can you make an example? (3.0) Teresa.
TERESA: All the loud noises you hear damage your hearing a bit and the damage of one...exposure to loud noises adds to the other ones...Like going to many concerts with very loud music...you don't get deaf after one of them, but the damage...increases...a bit.

[CS2-10B-2b, lines 674-681]

Extract 5.17

TEACHER: Yeah, so... we are the host, what was that word host, again? (1.0) What does it mean to be a host? Lea?
LEA: Uhm...in biology it means that uhm a virus...uhm but also bacteria...
TEACHER: Yeah, all of those.
LEA: Uhm, they kind of use you to live...inside you.

[CS1-10b-3, lines 23-28]

Interestingly, in Extract 5.17, Lea seems used to detecting academic terms and she answers by explicitly using metalanguage: "in biology it means" (line 25). It appears here that there is a sort of classroom culture about dealing with words that have different meanings depending on the register they are used with. In addition, when students provide an explanation of a technical term by using their own language (as both in Extract 5.16 and Extract 5.17), they are actually engaging in a shortened process of sensemaking, as they were *figuring out* how to verbalize an idea or a concept that so far only existed in their mind (cf. Odden and Russ, 2019).

To conclude, language-related questions can promote students' verbal production. Depending on how questions are asked, these questions can even facilitate sensemaking. However, their main purpose is to lessen linguistic barriers, to help students develop the language of the discipline and therefore facilitate learners' access to science. Overall, language-related questions are a discourse practice that contribute to answering RQ1.

This finding resonates with some questionnaire's results, specifically with the items *I worry when I hear new or unfamiliar words* and *How difficult is it to learn technical words?* As evidenced by Figure 5.9, most students almost never or only seldom worry when they are presented with new linguistic items. In addition, Figure 5.9 shows that students generally perceive as easy the task of learning new academic words. A possible interpretation of this may be that upper secondary level biology students already possess the discipline-specific knowledge that allows them to confidently integrate new information in an already well developed semantic network (cf. Jaipal, 2001). Another possibility is that students feel confident that any new lexical item will be explained.

What has been empirically proved by previous linguistics research in L1 settings is that biology language *is* lexically dense and that its "technical terms are not simply fancy equivalents for ordinary words" (Halliday, 2002, p. 176). The fact that upper secondary CLIL students do not see the introduction of new vocabulary as threatening and that, overall, the comprehension of upper secondary level biology concepts and ideas is not problematic (Figure 5.11), probably means that these students are supported in this aspect of biology learning. Duran *et al.* (1998) warn that understanding the intricacy of the interplay between prior knowledge, knowledge transfer (from L1) and the presentation of new information (such as new vocabulary) is complicated. With this data, it is not possible to correlate, for instance, the presence of language-related questions to positive perceptions about the introduction of new language and about the comprehension of new content. However, this possibility cannot be discounted either. Overall, it appears that in a CLIL environment, where language is carefully treated (Lo, Lin and Cheung, 2018), some aspects of content comprehension are benefited.

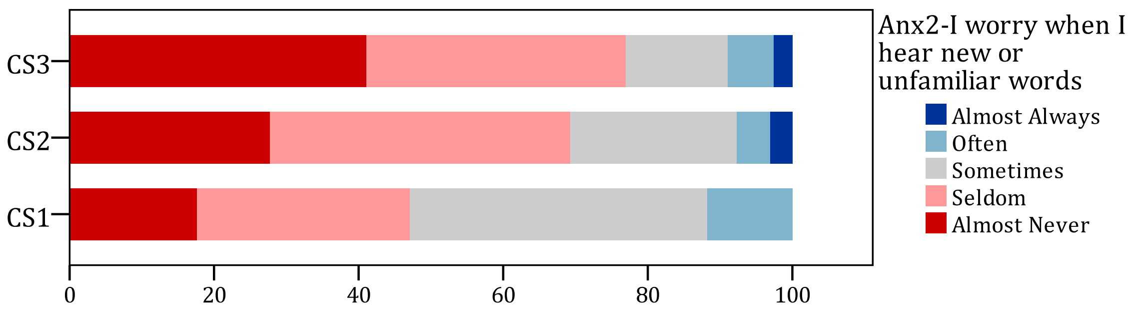

Figure 5.9 Percentages of questionnaire responses across case studies to the item *I worry when I hear new or unfamiliar words* (n = 160).

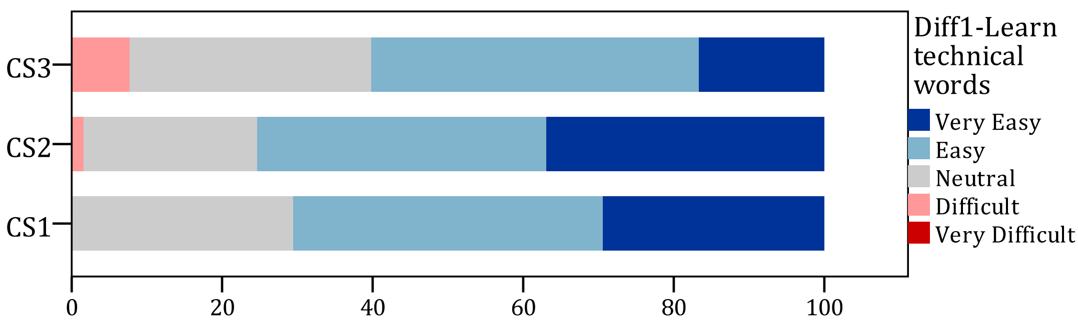

Figure 5.10 Percentages of questionnaire responses across case studies to the item *How difficult is it to learn technical words?* (n = 160).

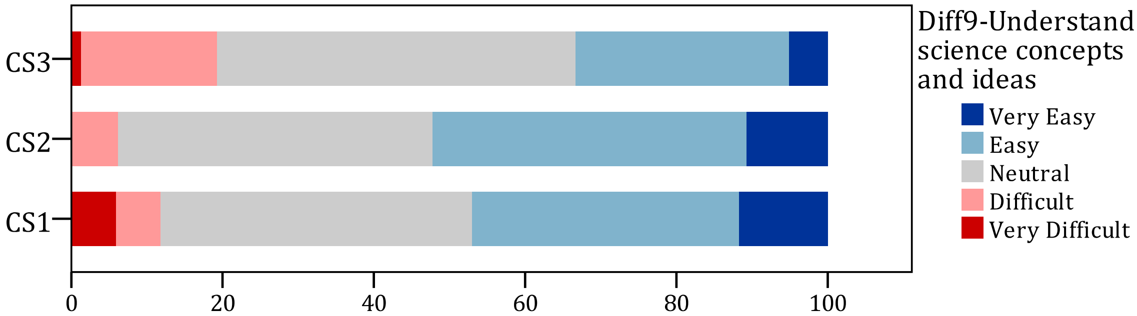

Figure 5.11 Percentages of questionnaire responses across case studies to the item *How difficult is it to understand science concepts and ideas?* (n = 160).

5.9 Teacher's Epistemological Beliefs and Verbal Production

The findings on the analysis of verbal production in students' answers across case studies (Figure 5.12) reveals that there are quite important differences in the distribution of long (longer-than-a-word) and short (one-word) answers across case studies. The most striking result is the poverty of long answers in CS3 compared to CS1 and CS2.

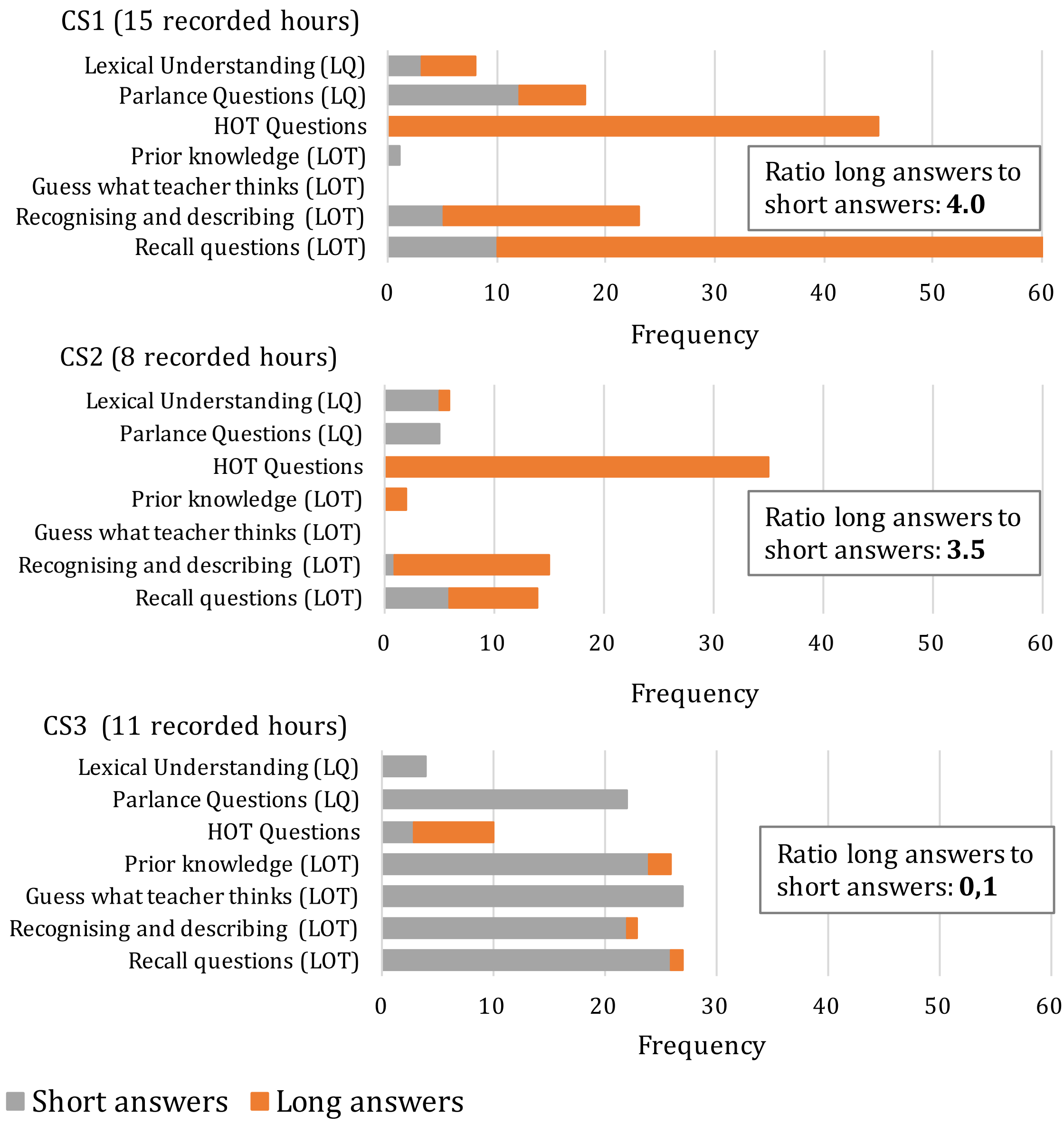

Figure 5.12 Frequencies of long (longer-than-a-word) and short (one-word) answers per question's type and across case studies. The ratio long-to-short answers is also indicated.

In order to investigate the reasons that underpin these results on verbal production, these findings from observational data are here integrated with some results extracted from teacher interviews. The thematic analysis conducted on teacher interviews reveals that teachers position themselves in relation to language in different ways. James—CS3 teacher—considers a student's language mostly as an instrument for understanding what is being explained. He is more interested in getting his students to "think and to understand" rather than to produce, as science learning "doesn't require a lot of language":

> I do not ask for complete sentences. I want concepts.
> I want that my students have the ability to think
> and to understand how something works and

> then to demonstrate that understanding which doesn't
> require a lot of language.

[James' interview, lines 211-215]

In contrast to this, the teachers of CS1 and CS2 both acknowledge that language has a value for its own sake. For instance, Emma (CS2) wants her students "to develop the language of science". For her, language has a value for its own sake and not only as a means to an end as for James:

> I want my students to understand biology, to get prepared
> for the exams, and to develop the language of science,
> both in English and German.

[Emma's interview, lines 26-28]

Emma's conceptual line between understanding and speaking is rather blurred: when her students are not able to *speak* about science she questions their *understanding* of science:

> Is it English or is it biology? Or is it me maybe?
> If it's English I try to give them a chance to say it
> in German.

[Emma' interview, lines 200-202]

The position of Alexandra (CS1) about using language orally for learning science is closer to Emma's. She also expects her students to speak about science and she notes that a linguistic lack of confidence in L2 may hinder participation in discussions. In addition, Alexandra openly values a participatory approach to learning, which is necessarily mediated by some kind of oral language production (cf. Sfard, 2009).

> And then sometimes it [speaking in L2] hinders
> some kids to talk confidently about the subjects […]
> when we do like great discussions […].
> So, what I think is that the greatest challenge for them
> is to have the confidence to talk in front of the class.

[Alexandra, lines 164-173]

If teachers' epistemological beliefs are crossed with findings about frequencies of HOT questions and students' verbal production a revealing pattern emerges. HOT questions and verbal production appear to be associated with a teachers' belief that language is an integral part of science and that speaking about science *is* an essential part of science learning (CS1 and CS2). By contrast, epistemological beliefs that relegate language to a tool for understanding someone else's production and that demote students' verbal engagement are associated with a dominance of LOT questions in general and GWTT questions in particular.

Despite the value of these findings, there is no evidence that a causal relationship exists between a teacher's language belief and classroom questioning practices. The findings of this study are limited in their ability to make such links due to the specific research design and small sample. Despite this limitation, the evidence collected calls for greater attention to the impact of teachers' language beliefs on pedagogical practices and questioning strategies used in CLIL science classrooms.

To conclude, teachers' epistemological beliefs about language seem to affect students' verbal engagement, students' participation in classroom discourse, and, indirectly, also cognitive engagement. So far, this is the first study that addresses teachers' language beliefs for their potential to affect classroom practices in a research field different from foreign and second language teaching (e.g. Borg, 2003; Farrell and Kun, 2007). In CLIL research, Hüttner *et al.* (2013) examined teachers' beliefs about foreign language learning, but their study did not provide any insights into how language beliefs affect learning environments.

5.10 Students' Perceptions about Questions' Difficulties

The questionnaire results on students' perceptions about how difficult it is to answer teacher's questions across cases reveal that students do not perceive as *difficult* neither what *is* cognitive engaging (i.e. HOT questions) nor what requires intense verbal production. Indeed, in CS1, where both the ratio long-to-short answers (Figure 5.12) and the count of HOT questions are the highest (see Table 5.2), students perceive answering to the teacher as a relatively easy task. By contrast, in CS3, where HOT questions are rare and the ratio long-to-short answers is the lowest, quite a few students perceive the task of answering as tough (Figure 5.13).

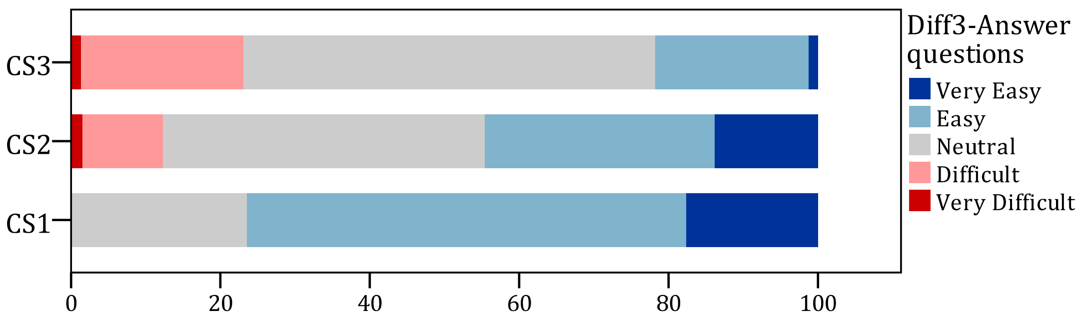

Figure 5.13 Percentages of questionnaire responses across case studies to the item *How difficult is it to answer questions* (n = 160).

This non-alignment between perception and empirical evidence of the level of challenge may let us think that some other element plays a role in this. It may be speculated that CS3 students are not used to being questioned individually and to take personal responsibility for their own answers. Therefore, they perceive it as difficult. To conclude, depriving science students of regular HOT questions and of the habit of producing extended answers may lessen learners' confidence about their ability to cope with science problems. This may be a side effect of neglecting to support HOT questions and verbal production in the science CLIL classroom.

5.11 Unsolicited Students' Questions

Along with teachers' questions and students' answers, the analysis conducted on classroom discourse also focused on how students' unsolicited interventions (i.e. students' questions) contribute to the creation of science learning opportunities. In particular students' questions were analysed for their potential of promoting verbal production, cognitive engagement and sensemaking. Students' questions are diagnostic in nature, as they provide indication of both conceptual non-understanding and linguistic gaps. Therefore, questions that work as "display[s] of incomprehension" (Svennevig, 2008, p. 337) are crucially important in science CLIL classrooms.

For analysing this source of data, students' questions were divided into two categories: *basic information questions* and *wonderment questions*, as proposed by Scardamalia and Bereiter (1992). The former are factual questions, whereas the latter are pitched at a higher cognitive level and indicate a deep learning approach that reflects "curiosity, puzzlement, scepticism or a knowledge-based speculation" (Chin and Brown, 2002, p. 524). Table 5.6 outlines the purposes these questions were asked for and their frequencies across case studies.

Table 5.6 Students' questions categories, their frequency across case studies and purposes (n = 108).

CATEGORY	Purpose	CS1	CS2	CS3
Basic Information questions	To seek for procedural or factual information/confirmation/exemplification.	(36)	(0)	(1)
	To ask for lexical meaning	(4)	(1)	(2)
	To ask for repetition	(0)	(0)	(4)
	(Total of basic–information questions:)	**40**	**1**	**7**
Wonderment questions	To clarify conceptual incomprehension or meaning	(23)	(3)	(0)
	To ask for deeper understanding	(8)	(0)	(2)
	Non-task curiosity	(9)	(1)	(14)
	(Total of wonderment questions:)	**40**	**4**	**16**

These results stand in contrast to those of Dalton-Puffer (2007, p. 103), who investigated students' questions in CLIL classrooms (not specifically in science classrooms). In her study, Dalton-Puffer discovered that the most common questions that CLIL students ask are questions about new vocabulary and that content-related questions are very sporadic. By contrast, in this study, most of the questions students asked in all three case studies were decisively content-related.

5.11.1 Basic Information Questions

In this study, basic information questions were mostly asked for requesting procedural of factual information, as in the following two examples:

> S: Uhm, but... which value is x? [CS1-11-1b, line 91]
>
> S: Can you make an example? [CS1-11-1b, line 365]

It is apparent here, that this kind of questions are not cognitively demanding. However, their display is important because they clarify emerging doubts and prevent possible misunderstanding. These questions require high reactivity from the students, meaning that they only make sense if asked as soon as the doubt or uncertainty emerges. In this sense, *basic information questions* are important for fostering conceptual understanding.

Occasionally students asked for the lexical meaning of both technical and non-technical terms, as in the two following examples:

Extract 5.18

S: What is a...petri dish?
TEACHER: Petri dish [writing the word on the board] is a *Petrischale <petri dish>*. Same thing. We used it in the lab [...]
[CS1-10A-2, lines 219-221]

Extract 5.19

TEACHER: Okay and... can you tell us what's the most likely of them?
LEA: Most likely?
TEACHER: Yeah, the most probable.
[CS2-10A-2b, lines 560-563]

Although questions in Extract 5.18 and Extract 5.19 signal a linguistic gap, if not addressed they ultimately hinder conceptual understanding. In various CLIL classrooms (not specifically in science classrooms), Dalton-Puffer (2007, p. 103) found that this vocabulary-related questions are the most common CLIL students ask. Dalton-Puffer's finding is not confirmed by this study.

In CS3, some requests for repetitions were observed. Again, these are questions that are pitched at low cognitive engagement. Nevertheless, it is important that they emerge and that are addressed. Otherwise, students may get lost in classroom discourse.

Overall, all basic information questions are ultimately important for conceptual understanding in a CLIL science classroom. In addition, they also promote verbal production and boost students' confidence that by actively participating in classroom discourse they improve their understanding. Based on this evidence, it seems that a classroom culture that promote basic information questions is important for promoting opportunities for learning science.

5.11.2 Wonderment Questions: Asking for Conceptual Clarification

The *requests for conceptual clarification* play an important role in the science classroom, as their display of non-understanding informs the teacher that the students are not ready to proceed (Kääntä and Kasper, 2018). They have also been labelled as "negative epistemic claims" (Lindström, Maschler and Pekarek Doehler, 2016, p. 73). In regular science classrooms, these questions clearly indicate an issue related to conceptual understanding. However, this may not always be the case in science CLIL classrooms, where an apparently *conceptual* problem may be *linguistic* instead and teachers may not understand this. In second language instruction, Markee (1994) notes that students' requests for clarification are regularly taken to signal a gap in their L2 vocabulary. On the contrary, Koole (2012) notes that in a linguistically diverse mathematics class the teacher consistently diagnoses students' understanding problems as either conceptual or procedural math problems and never as language-related.

In these data, the linguistic/conceptual ambiguity was never observed. Occasionally students had literacy issues, meaning here linguistic doubts that are also conceptual in nature, as in Extract 5.20.

Extract 5.20

ANA: You said replication, but (1.0) what do you mean? (1.0) Uhm (1.0)
not mitosis and meiosis?
TEACHER: Not mitosis or meiosis. We've already talked about
that. That's cell replication.

[CS1-11-2, lines 22-25]

Here, the word *replication* is ambiguous because it has different meanings depending on the context it refers to. A similar situation has been encountered in an already mentioned extract, when Maia is confusing the words/concepts *allele* and *antigen*:

Extract 5.21

MAIA: Ehm...what's the difference between an allele...and a
(2.0) an...antigen?

[CS2-10A-2b, lines 463-464]

As evidenced by Extract 5.20 and Extract 5.21, clarification questions focused on science language promote both conceptual understanding and the development of academic language. In general, clarification questions entail some intense cognitive engagement because: (a) the asking student has to realize that there is a gap in his or her knowledge or an incongruence with his or her cognitive reference frames; (b) the same student needs to be able to pin down exactly what that gap or incongruence is; (c) finally the student needs to be able to formulate a clear question about it. This process may bring the student to a very demanding language production, as in the following Extract 5.22 (the student' s request for clarification has been underlined by the author):

Extract 5.22

JULIA: There is the bond. But <u>I don't quite get the role of the
ribosome</u>. So, the ribosome has the mRNA and the tRNA has
the comple...mentary triplet…to the mRNA and the amino acid.
So, the protein can be made in the ribosome, and…
TEACHER: Yeah. *At* the ribosome, not *in* the ribosome.
JULIA: Hmm, at the ribosome, and then the, um, the dipeptide

bond is between the AUU of tRNA there and...
TEACHER: No. No, not between the AUU, not between the triplets. Only between the amino acids that the tRNAs carry. So the role of the ribosome guys is to be a meeting place. The role of the ribosome is to enable the meeting between the tRNA and the mRNA. Right? (2.0) In the right order.

[CS1-11-4a, lines 322-333]

In Extract 5.22, Julia is wondering about the role of a cell component in the process of protein synthesis. Because pinning down her gap is not easy to her, she opts for systematically repeating what she understood so far. She probably realizes that there must be something wrong in there, otherwise things would make sense! As soon as the teacher detects the problem in Julia's explanation, she interrupts her, corrects her mistake and subsequently offers the answer. Julia's situation is labelled by Koole (2012, p. 1902) as an "epistemic paradox", which surfaces when students ask their teacher for help with a learning issue and have to deal with the fact of having to "know what they don't know" or "understand what they don't understand". In other words, the student lacks the knowledge or the understanding to exactly explain what the problem is and the teacher assumes or presupposes the problems and explains what he or she thinks that the problem is. For conceptual clarification questions to be successful (i.e. triggering the right teacher's answer) they should be as precisely formulated as possible. This would mean for students to engage in intense and precise verbal production. However, in the CLIL classroom, language competence may be sub-optimal. In this study, teachers were observed using their content knowledge and teaching experience to compensate students' linguistic limits and infer from the students' few—and sometimes disjointed—words what the cognitive gap is. Extract 5.23 represents one of these cases.

Extract 5.23

SAMUEL: And...one standard deviation (2.0) and how much exactly (3.0) uhm...is it always different?
TEACHER: It's always different, it depends on your sample.[…]The closer your values are to the mean, the smaller is the standard deviation[…]

[CS1-11-1b, lines 221-222]

Samuel is trying to figure out the meaning of the concept of *standard deviation*. Samuel is thinking while asking his puzzlement question. His idea of standard deviation improves while formulating his question: from thinking of standard deviation as an absolute value, he ends with thinking of it as a relative value. In this example, it is apparent how thinking and communicating are not two separated processes (Sfard, 2008; Vygotsky, 1986). In this sense, students' questioning is also important as a means for sensemaking.

Sometimes students need to test their ideas and their questions also serve this purpose, as in Extract 5.24.

Extract 5.24

THEO. I just have a question. Uhm...Has it also something to do with...because rod cells are more sensitive to light?
TEACHER: Yes, that's exactly what it has to do with. Well Done!

[CS1-10A-1b, lines 536-539]

In this example, Theo just had an intuition about how eye receptors work. His question helps the teacher to move forward by linking her explanation to what Theo asked. In this sense, students' questions contribute to the progression of the whole classroom discourse.

As evidenced by the extracts reported so far, students' questions play an important role in developing conceptual understanding in the CLIL science classroom. However, it may be expected that not all CLIL students possess adequate L2 linguistic resources to ask about their conceptual gaps or to have their conceptual intuitions confirmed. In Extract 5.25, Ida shows how this issue may be solved:

Extract 5.25

IDA: *Das macht aber keinen Sinn. Sollte es nicht das Gegenteil sein*? <It makes no sense. Shouldn't it just be the opposite?>

[CS2-10A-1, lines 35-37]

Ida simply switches to her mother tongue to express her puzzlement about the eye anatomy. How languages can be used as resources is analysed in the next chapter. Here, I only acknowledge that students' questioning in the CLIL classroom benefits from the use of L1 for conceptual understanding. Use of L1 may help the students to keep the focus on their cognitive engagement. This observation is consistent with what Alexandra (CS1 teacher) claims in her interview:

> […] if I say 'Explain it in German', then sometimes, some kids would say something—who rarely speak otherwise.

[Alexandra's interview, lines 169-171]

Therefore, if language is too overwhelming for asking for clarification, resorting to L1 may be a really good option, one that Alexandra encourages:

[…] we use German to understand.

[from Alexandra's interview, line 181]

To sum up, from the analysis of students' questions it emerges that conceptual clarifying questions contribute to promoting academic language development and students' cognitive engagement. This happens in the phase of formulating questions: students get engaged in verbalizing and developing their thoughts and use their cognitive skills to pin down their conceptual gaps. Also, the phase when the teacher answers the students' questions promotes conceptual understanding as the students get specific answers to their puzzlements or to their confirmation requests. In unsolicited interventions, verbal production may be a limiting factor that hinders or blocks the genesis of questions. In these cases, linguistic flexibility (e.g. student's code-switching and a teacher's solid content knowledge) can minimize the negative effects of a lack of language competence. Overall, in the CLIL science classroom, students' questioning appears as a practice conducive to generating opportunities for learning science, and thus they contribute to answering RQ1.

5.12 What Facilitates Students' Questioning

As students' questions facilitate opportunities for learning science, it would be interesting to investigate what factors facilitate students' questions. Language flexibility already emerged as a facilitating factor. In order to better investigate this dimension, a comparison between case studies is here undertaken. Figure 5.14 displays a clearer overview of the distribution of students' questions across case studies.

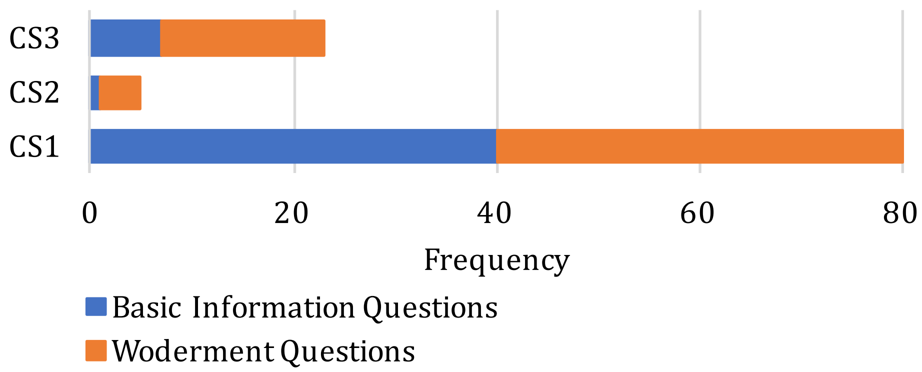

Figure 5.14 Students' questions (n = 108) across case studies.

Although present in all the observed case studies, students' questions were not equally distributed across them. Both *basic information questions* and *wonderment questions* are relatively common in CS1. Interestingly, basic information questions are far less frequent both in CS2 and CS3.

Correspondingly, where students' questions are more common they are also perceived as easier to ask (Figure 5.15). However, from the analysis of the available data, it is impossible to say whether CS1 students ask more questions because they perceive this as an easy task or whether students' questions are perceived as easy *because* CS1 students are used to asking them.

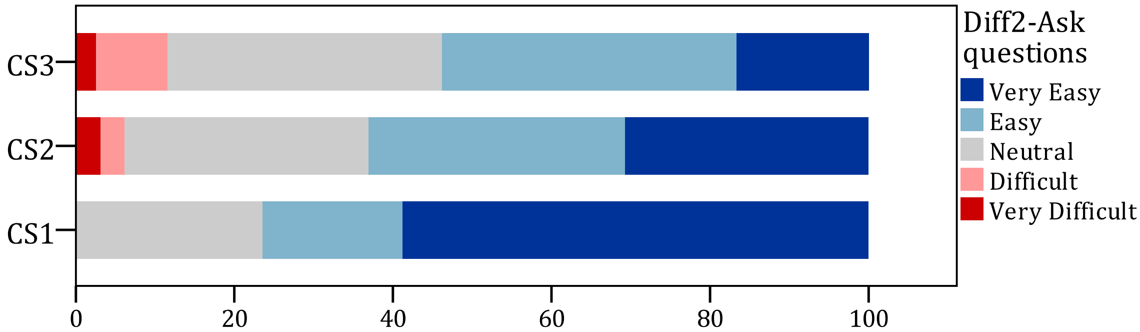

Figure 5.15 Percentages of questionnaire responses across case studies in relation to the item *How difficult is it to ask questions* (n = 160).

Previous research has identified many factors that enhance or constraint students' questioning in the science classroom. For instance, Chin and Brown (2002) note that problem-solving activities tend to elicit questions from the students. In our study, it is difficult to connect specific types of activities to a high or low frequency of students' questioning. However, this study confirms Lemke's (1990) observation that more students' questions often come in bulk, as one student's question may be felt as an invitation for other students to ask their own questions. These sequences of students' questions are labelled in this study as *Student-Questioning Dialogues* (from Lemke, 1990, p. 52). These are extended forms of dialogue initiated by students' questions and were only found in CS1. In the other two case studies, student-initiated dialogues were limited to one single exchange. This lack of evidence of students' questions in CS2 and CS3 could stem from either a lack of students' language skills and/or of confidence, or from a lack of classroom culture for openly inquiring.

In terms of cognitive engagement, students' questions seem to reflect how students adapt to learning settings and teaching styles. For instance, in CS1, the abundance of questions pitched at a high cognitive level (as evidenced by Table 5.6 and Figure 5.14) may reflect the numerous HOT questions asked by the teacher. Also, the relative abundance of *basic information questions* (again Table 5.6 and Figure 5.14) could be explained by the comfortable discursive environment supported by the CS1 teacher through many elicitation moves, as in Van Zee *et al.* (2001).

The CS2 teacher also supported a similarly comfortable discursive environment. However, in CS2, *basic information questions* are absent and *wonderment questions* are rare. The scarcity of students' questions in CS2 is more problematic to explain. Teacher's HOT questions were common in this case study, as they were common in CS1. In addition, also CS2 students demonstrated an ability to produce extended answers when requested. What may make a difference here is the perceived different role of the teacher. Two of the four *wonderment questions* found in this case study (both asked for clarification of non-understanding) were followed by the student's questions being rebroadcasted to the whole-class instead of being answered by the teacher herself (as in Extract 5.3). Extract 5.26 offers another example of this situation.

Extract 5.26

LUCAS: I don't understand. According to that picture we shouldn't be able to see much red…either. But…we see red.
TEACHER: You're right Lucas. Can anybody think a reason why we still see red even if we don't have a peak of sensitivity at the wavelength of red? (5.0)

[CS3-11-1a, lines 93-97]

It appears that in CS2, the teacher generally treats students as responsible actors of their own learning. Accordingly, it could be speculated that the low number of students' questions in CS2 may somehow be linked to the fact that CS2 students feel more responsible for finding answers themselves and rely less on the teacher. These are insights generated by the data analysis. Whatever the causes are for the lack of students' questions in this case study, this result is at odds with what students claim to perceive. Figure 5.16 shows the results of the questionnaire responses about the question *I ask questions to the teacher*.

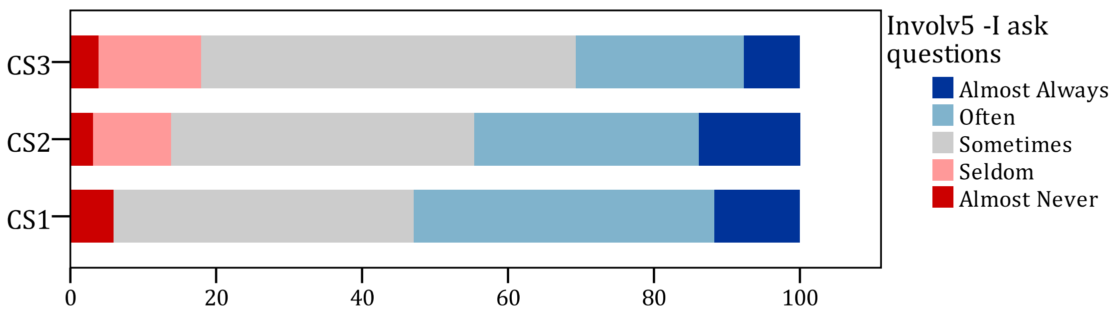

Figure 5.16 Percentages of questionnaire responses across case studies in relation to the item *I ask questions to the teacher* (n = 160).

CS2 students claim to ask nearly as many questions as in CS1. Therefore, if this result is used for triangulating results from the analysis of classroom discourse, it reveals a discrepant account which may be explained by the students' lack of awareness.

In CS3, the scarcity of questions asked for deeper understanding or for clarifications by the students (Table 5.6) could reflect the lack of HOT questions asked by the teacher. By contrast, CS3 students produced a relatively high number of *wonderment questions* driven by off-task curiosity, meaning that the students often asked about what intrigued their curiosity and about what was only loosely related to the topic at hand (cf. Pearson and West, 1991). These students' behaviours could reflect James' curious nature, which he encourages in his teaching. It may help to note here that James was observed occasionally digressing from the topic or indulging in anecdotes and little stories made up at the moment, which the other two teachers never did. By asking the teacher questions out of curiosity reinforces James' role as omniscient expert, which he plays very well. Even though *off-task curiosity* questions increase students' participation they do little for the building of meaningful scientific knowledge. They do promote some verbal production, but very little cognitive engagement is involved.

Overall, as Carlsen (1991) suggests, student questioning is a complex phenomenon, characterized by the interactions of context, content and reactions to questions. In CLIL classrooms the dimension of context is complicated by the language factor which may negatively affect the willingness to spontaneously communicate (MacIntyre, Dörnyei, Clément and Noels, 1998) or which may even limit epistemic access (as in Kääntä and Kasper, 2018).

5.13 Conclusions

This chapter mainly contributed to answer research questions RQ1, RQ3 and RQ4. A summary of the findings produced in this chapter is provided by Table 5.7. This section discusses the emerging key findings with some considerations about their significance and implications for teaching science in a CLIL setting.

Teachers' questioning—embedded in IRFRF sequences of dialogue (Mortimer and Scott, 2003)—promotes conceptual understanding in the upper secondary CLIL science classroom, which confirms what was found in L1 science classrooms but never before in bilingual classrooms (e.g. by Chin, 2007; Smart and Marshall, 2013; Yip, 2004). This is the first study in science education that closely looked at teachers' questioning as a tool for promoting science understanding in bilingual settings and builds on what Ernst-Slavit and Pratt (2017) achieved by investigating primary science classrooms with multilingual students. In particular, it was found that HOT questions promote both cognitive engagement (schematic and strategic knowledge) and verbal production about science. However, high cognitive engagement only takes place when students verbally communicate their thoughts beyond the one-word answer, which confirms Vygotsky's theory of thought and language (Vygotsky, 1986). This has important practical teaching implications, as over-simplifying the linguistic task of students (e.g. by only requesting one-word answers) leads to over-simplify the disciplinary content in terms of cognitive engagement, thereby stripping it of what makes it potentially appealing to upper secondary students.

When HOT questions are oriented to *figure things out* and are strategically placed, they can also lead to sensemaking. In this study, it was observed that science sensemaking is promoted when teachers' questions are strategically placed and contingent on students' answers. This process is facilitated by translanguaging practices, meaning that science content becomes meaningful to students when it builds upon students' everyday language (e.g. when students explain science by *using their own words*) and students' mother tongue. Up to now, there has been little research on sensemaking in bilingual science classrooms (but see Brown *et al.*, 2005; Warren *et al.*, 2001). This is the first study in science education addressing sensemaking as a discourse practice in CLIL classrooms. Furthermore, this study identified some practical strategies to scaffold cognitive engaging questioning (e.g. probing) in CLIL science classrooms that worked for the investigated classrooms (upper secondary level) and that could also work outside the context of this research.

In this study, students' questions were not particularly frequent but they were nevertheless present, even though they were not evenly distributed across the three case studies. In addition, students' questions tended to be content-related instead of being language-related, which is contrary to what Dalton-Puffer (2007) found in her study on CLIL classroom discourse (but not specifically science classroom discourse). In this study, it is not clear what aspects of the classroom environment or of the teaching facilitated students' questions. As this activity is at the heart of scientific inquiry and, more generally, of science learning (Chin and Brown, 2002), it would be important to further investigate this aspect.

Overall, the discourse practices observed in this study are significant in two ways. First, they offer both practitioners and researchers ways of understanding issues of content access through real-life examples. Second, the discourse practices emphasize the importance of considering classroom discourse in addressing access to science. These findings could be used to inform in-service science teachers in CLIL teaching programmes and raise awareness of the role of spoken language in science classroom discourse for building conceptual understanding.

The findings presented here may also guide science teachers to reflect about how and why they question their students and about how they conceptualize language for schooling. For instance, it emerged that a high frequency of higher order thinking questions seems connected to a teachers' belief that speaking about science *is* intrinsic to science learning. By contrast, a dominance of lower order thinking questions without verbal production (as in the GWTT types of questions) appears to be associated with an epistemological belief that relegates language to a tool for understanding someone else's production and that demote students' verbal engagement. Further research is needed to investigate this possible causal link.

In relation to science language development, it was discovered that CLIL science teachers often interrogate their students about the meaning of academic words or to prompt the use of science language. The examples from this study offer suggestions that may be used by CLIL teachers to enhance how to embed the teaching of academic language in classroom discourse. Indeed, science teachers may feel not at ease at explicitly teaching language (Airey, 2012). These findings could be used to dispel the notion that language teaching is neither science teachers' responsibility nor a significant aspect of science teaching, CLIL or non-CLIL. This study offers exemplars of how different teachers, with different professional backgrounds and different epistemological beliefs smoothly incorporated linguistic aspects into their teaching without making it sound at odds with the rigor of science content and processes. These exemplars may be used in teacher education programmes.

While dealing with CLIL environments, this study focuses on science learning and interprets learning phenomena through the lens of science education. For this reason, while providing insights into the learning of content in CLIL settings, the findings also offer practical examples and suggestions about how to facilitate science learning opportunities in non-CLIL settings.

Table 5.7 Overview of findings from Chapter 5 in relation to research questions.

Research questions	Key Component	Findings from Chapter 5
RQ1 - What **interactional discourse practices** facilitate **opportunities for learning science** in three case studies involving German and Italian upper secondary level science classrooms when a CLIL approach is implemented?	Conceptual understanding	*Conceptual understanding is promoted by:* - HOT questioning - Contingent questioning - LOT Questioning + strategic questioning (when there is verbal production) - Students' questions - Language-related questions when students provide an explanation of a technical term by using their own language (form of sensemaking) *Teacher's strategies:* - giving time to discuss problems first with peers; - rephrasing questions to make them clearer; - increasing wait-time; - giving clues to nudge thinking in the right direction; - using strategic placement of questions (e.g. extending, probing, challenging)
	Science language development	*Science language development is promoted by:* - Language-related questions (e.g. parlance questions) → science language development in general - Language-related questions when teachers ask for examples or for functional meaning of a term) → language use in context - Language-related questions when students provide an explanation of a technical term by using their own language. *Teacher's strategies:* - giving time to discuss problems first with peers; - rephrasing questions to expose students to the lexical repertoire they need for answering them; - increasing wait-time; - inviting to use any language for answering; - contingent questioning: splitting long answers in chunks
RQ3 - What are teachers' goals and **epistemological beliefs** about teaching science through a CLIL approach and **how do they affect classroom practice**?	Teachers' goals and epistemological beliefs	A teacher's types of questions (e.g. HOT, LOT questions) and, indirectly, students' oral production/cognitive engagement seem to be affected by the teacher's beliefs about language use in the classroom. In particular, when spoken language is considered relevant for science learning by the teacher (as declared in interview), students are engaged in relatively long answers that are able to support cognitive engagement.
RQ4 - What are **students' perceptions** of learning science through a CLIL approach?	Students' perceptions	Depriving science students of regular HOT questions and of the habit of producing extended answers lessens learners' confidence about their ability to cope with science problems.

Chapter 6 Making Science Accessible

I try to connect with what they know already from common knowledge about subjects and [...] we use animations, short videos, models, PowerPoint presentations that visualise this...experiments [...]. So, you try essentially to make it accessible in any number of different ways by anyone, because these are sometimes pretty abstract content.

[Alexandra, CS1 teacher]

6.1 Introduction

Chapter 5 explored how science concepts are built through discourse by using an analysis of classroom discourse focused on interactions as the investigative tool. This chapter shifts focus from interactions to teacher actions and examines and unpacks classroom discourse with the main purpose of understanding how science knowledge and epistemologies are accessed and how science language development is promoted though classroom dialogue. The chapter is essentially guided by the second research question (RQ2) addressing teaching discourse practices that promote/facilitate opportunities for learning science.

The main investigative tool used in this chapter for analysing classroom discourse is thematic analysis. The analytic focus guiding the application of thematic analysis is grounded within an interpretivist approach to data analysis and adopts a sociocultural approach to learning. The thematic analysis conducted on classroom transcripts is mainly inductive, i.e. data-driven. However, some aspects of discourse, such as metadiscourse, are explored using theory-derived coding strategies. The methodological aspects of this analysis are detailed in section 4.14. Findings derived from using this analytic strategy are compared and integrated with findings obtained from teacher interviews and student questionnaire responses. This integration process produces thick descriptions of how opportunities for learning arise in CLIL science classrooms and enhances the validity of the whole study. The implications of the practices emerging from this analysis are also examined.

In terms of organization, the chapter is introduced by an overview of the themes emerged from the thematic analysis conducted on the transcripts of classroom discourse. This overview of themes is followed by a presentation of how these themes address the research questions in conjunction with other research components (data from questionnaire analysis and from teacher interviews).

Subsequently, key findings are presented and discussed. Overall, the chapter is organized around key findings. This means that the emerged themes are not analysed and discussed one by one as it is often done in the tradition of thematic analysis, as for instance in Bungum, Bøe and Henriksen (2018). How themes, subthemes and codes work together to answer the research questions structures the presentation of findings instead. This is in line with the research paradigm that underpins this study, i.e. the pragmatic paradigm, which considers modes and methods as instrumental for answering research questions. To help the readability of the interplay between themes, subthemes and various research components, visual overviews are provided throughout the chapter. A selection of extracts from classroom dialogue and teacher interviews transcripts support the analysis. Parts of extracts have been underlined by the author to make the link between raw data and analysis more readable.

6.2 Thematic Analysis of Classroom Discourse

Classroom transcripts were integrated with data from classroom observations at an early stage of the analysis process. These data were then examined using an interpretative approach to thematic analysis (Clarke and Braun, 2017). The aim of the analysis was to identify teaching practices that promote/facilitate opportunities for learning science (i.e. RQ2). Teaching practices were coded and analysed on utterance level. Themes were developed in order to cluster the codes that emerged from raw data around a number of main ideas relevant to the research questions. From the beginning, it was apparent that codes clustered around two main concepts: *content building* and *language using,* namely the two overarching themes of this analysis. Among these two overarching themes, five themes were extracted. These themes (listed in Table 6.1) provide the best mapping of the data in relation to the research questions.

Table 6.1 Themes and overarching themes generated through the thematic analysis.

Content building	**Language using**
(1) Building science content (the what we know and why it happens): - *Presenting science content* - *Supporting science content* (2) Building Nature of Science (NOS) understanding (what science is and how science works)	(3) Talking about talking - *Metadiscourse* - *Metalanguage* (4) Using redundancy (5) Using language as resource

The drawing of a visual thematic map (in Figure 6.1) facilitated the exploration of the relationship between themes.

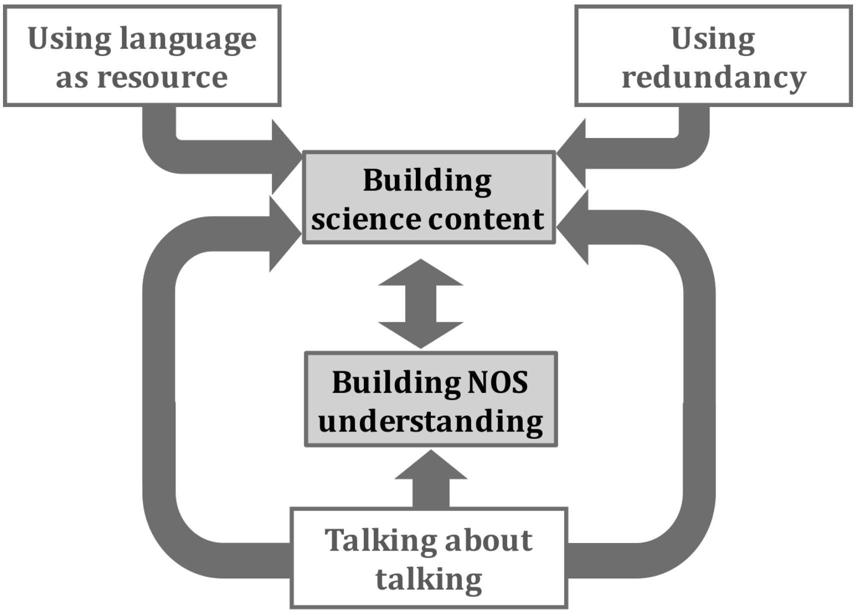

Figure 6.1 Visual summary of relationships between themes.

This visual thematic map illustrates how themes work together in telling the global story about the data. In this analysis, the overall story that underpins all themes is the building of science knowledge through language. The first important observation that emerges is that the core around which the analysis coheres is made of both the *building of science content* (i.e. the 'what we know' and the 'why it happens') and the *building of Nature of Science (NOS) understanding* (i.e. the 'what science is' and 'how science works') themes. These two themes compose the overarching theme of *content building*.

This result indicates that teacher discourse is focused both on science content and on science nature. Although, the focus on science content is dominant and explicit, also elements that relate to the Nature of Science (NOS) are embedded in the discourse texture. As evidenced by the literature reviewed at the start of this research study, there is a growing consensus that teaching how science works is at least as important as teaching the content of science knowledge (Lederman, 2007). The presence of elements of the NOS in classroom discourse positively influences the opportunities students have to learn science (as understood by Stevens, 1993).

The three themes clustered under the umbrella overarching theme of *language using* point to the core themes, meaning that content building is mediated by language use. In particular, the two themes *using language as resource* and *using redundancy* mediate the building of content, whereas the other theme, *talking about talking* mediates both the building of content and the building of science epistemologies and values. This means that practices that make use of metadiscourse (or *metatalk*, as called by Schiffrin, 1980) and metalanguage have a broader use, as they help to both better understand content and develop scientific values and epistemologies. By contrast, translanguaging and codeswitching practices (*using language as resource*) and the many forms of repetitions (*using redundancy*) mediate more specifically the *building of scientific content* theme. These relationships between themes were derived from a cross-analysis of the themes' codes. As strings of text may contain more than one code, these more-than-one-code strings of transcript were checked across themes. Consistencies of one theme's codes with the codes of another theme were considered indications that the two themes were related. These are what Hayes (1997) called cross-references.

Table 6.2 provides a comprehensive list of the codes clustered under their themes (thematic map). The counts of occurrences of each code are given in brackets. These frequencies do not necessarily measure the significance of a theme/code. Instead, they are meant to give an indication of the extent to which a particular theme/code is particularly recurrent across the whole data set.

Table 6.2 List of the codes, themes and sub-themes. Within each theme and subtheme (if present), codes are listed from the most to the less frequent ones. Counts of occurrences are given in brackets.

1) Building science content	**(3) Talking about Talking**
Presenting Science Content	*Organizational metadiscourse*
Drawing upon prior knowledge (222)	Activity Connectives (197)
Explaining logically (78)	Knowledge Connectives (193)
Defining (73)	Text connectives (172)
Inquiring (64)	*Evaluative metadiscourse*
Describing and Labelling (57)	Attitude markers (273)
Seeing the Big Picture (10)	Epistemology markers (53)
Supporting Science Content	*Interpretive metadiscourse*
Using examples (100)	Code glosses (259)
Using visuals (98)	Interpretive markers (129)
Using analogies and similes (66)	*Metalanguage*
Using direct quotes (51)	'In biology we say' (241)
Using videos/animated demonstrations (18)	
Using anecdotes (14)	**(4) Using Redundancy**
	Self-paraphrasing while lecturing (154)
(2) Building NOS understanding	Reformulating students' answers (124)
Science is based on evidence (33)	Restating students' answers (94)
How scientists work (21)	Using synonyms (71)
Science is not certain (11)	Rephrasing questions (53)
Science is based on observation (10)	Reiterations (48)
Science changes over time (6)	Repetitions as a rhetoric device (39)
	Student repetitions with hesitation (19)
	Student repetitions with variation (6)
	(5) Using Language as Resource
	Student single word in L1(34)
	Teacher mixed language (30)
	Teacher's single word in L1 (21)
	Providing translation (30)
	Student answering in L1 (20)
	Teacher's everyday language (15)
	Asking students for translation (10)
	Teacher extended use of L1 (9)
	Student mixed language (7)
	Using cognates (5)
	Inviting to use any language (3)
	Requesting to explain in L1 (3)

6.2.1 Themes and Research Questions

Table 6.3 outlines how themes that emerged from the analysis of classroom transcripts mainly address research question RQ2. Because the theme *using language as resource* refers to interactional practices that regards both teachers and students, its analysis contributed to answering RQ1.

The interpretation of data is guided by the following elements: (a) conceptual understanding of science content, (b) understanding of science epistemologies and values, and (c) science language development. These components have been identified as constitutive of the concept of opportunities for learning science in a CLIL setting framed within a sociocultural approach as explained in section 3.7.2.

RQ3 is mainly investigated through the thematic analysis of teachers' interviews (as illustrated in the previous chapter). Codes and themes from the analysis are integrated and jointly presented with data from the analysis of the classroom transcripts and contribute to producing richer qualitative findings about classroom practices. RQ4 is investigated with the results from the statistical analysis of student questionnaires. These results are also integrated and jointly presented with data from the analysis of classroom transcripts.

Table 6.3 Relationship between research questions, key component underpinning each research questions, and themes and questionnaire results from data analysis.

Research questions	Key Component	Themes and questionnaire results from data analysis
RQ1 - What **interactional discourse practices** promote opportunities for learning science when a CLIL approach is implemented at upper secondary level?	Conceptual understanding + Science language development	*Themes from the analysis of classroom transcripts:* **Using language as resource** (code-switching and translanguaging)
RQ2 - What **teaching discourse practices** facilitate opportunities for learning science when a CLIL approach is implemented at upper secondary level?	Conceptual understanding	*Themes from the analysis of classroom transcripts:* **Building science content** **Building NOS understanding** **Talking about talking** (Metadiscourse: attitude markers, interpretive markers, epistemological markers, organizational metadiscourse) **Using redundancy** (paraphrases, synonyms, rephrasing of questions, re-teaching)
	Science language development	*Themes from the analysis of classroom transcripts:* **Using language as resource** (code-switching and translanguaging) **Talking about talking** (Metadiscourse: code glosses Metalanguage) **Using redundancy** (paraphrases, synonyms, reformulations of students' answers)
RQ3 - What are **teachers' goals and epistemological beliefs** about teaching science through a CLIL approach and how do they affect classroom practice?	Teachers' goals and epistemological beliefs	*Themes from analysis of teacher interview* **Language use** (L1 using, knowledge transfer to L1) **Teacher's responsibility** (adapting to (students' needs, looking for feedback, making science more accessible, science language teaching, repeating)
RQ4 - What are **students' perceptions** of learning science through a CLIL approach?	Students' perceptions	*Descriptive statistics on questionnaire items:* Ideas on NOS Perceived understanding of teacher's explanations Perceived flexibility of teacher's explanations Perceptions on L1 use

6.3 A Roadmap through Science Content Presentation

The analysis and discussion of results from thematic analysis of classroom transcripts starts by analysing the theme *building science content*. As this theme has two subthemes, these are separately analysed. In particular, this section focuses on the subtheme *Presenting science content* and aims to understand what dialogue practices promote conceptual understanding as framed within a sociocultural and communicative approach to learning.

In the examined CLIL classrooms, science content was presented using a variety of actions in sequences that can be approximately illustrated by Figure 6.2.

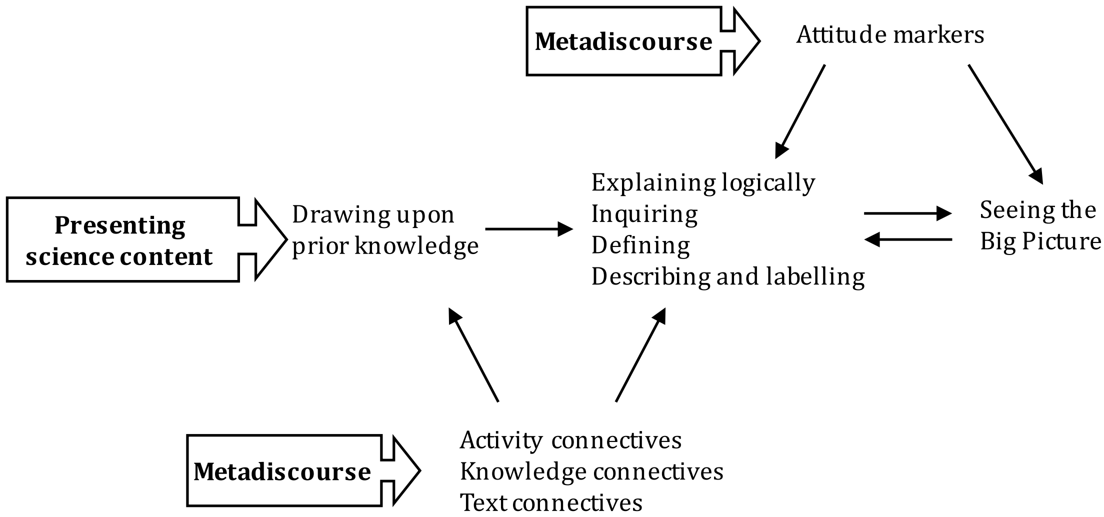

Figure 6.2 Scheme of how *presenting science content* and *metadiscourse* work together in the CLIL classroom to generate opportunities for learning science.

In the examined science CLIL classrooms, content is mainly provided to students in the form of talk (triadic dialogue) and, secondarily, through short monologues. In both cases, science teachers: (a) draw upon students' prior knowledge; (b) use scientific reasoning to explain concepts, objects and processes; (c) define concepts, describe objects and processes and labels parts of them as part of their teaching practice. A large amount of talk is dedicated to describe and define rather than to actually explain. This is in line with what also Ødegaard and Klette (2012) found in L1 science classrooms and resonates with what Ogborn *et al.* (1996) highlight about the problematic link between explanations, descriptions and definitions in the science classroom. Ogborn *et al*. argue that teachers need to focus on the importance of understanding (and describing) the parts of a concept, a model or of a process, before actually explaining it. "For these reasons, much of the work of explaining in science classrooms looks like describing, labelling or defining" (Ogborn *et al*.,1996, p. 13-14). Only after the parts are known, can learners begin to understand how they work together and see the whole picture. At this point the focus of explanations can shift and move from details to big-pictures. And then the big-pictures are brought into even bigger-pictures, which help to contextualize the topic or to close it. All along, guided discussion is used to motivate students to acquire necessary entities and guide them to model self-explanations and build sensemaking (as explained in Chapter 5). This pattern was observed in the classroom talks of all three case studies. For instance, Alexandra (CS1) needs to introduce students with different types of RNAs, with ribosomes and amino acids working together in way, before explaining how proteins are made. Emma (CS2) first explains how the inner ear is built and then how hearing works. James (CS3) first explains the anatomy (the entities) before getting to the physiology (the how things work) of the digestive system.

Linking new elements and concepts to familiar ones also helps navigate students through the large amount of entities that make the building blocks of biology. Indeed, references to prior knowledge were among the most common codes throughout the whole data set. The value of connecting with students' knowledge is also explicitly recognized by Alexandra (CS1):

> Well, I try to connect with what they know already from common knowledge about subjects.
>
> [Alexandra's interview, lines 85-86]

In this study, it was found that these connections are facilitated by teachers' use of metadiscourse (see Figure 6.2). This finding was obtained by analysing those parts of transcript text marked with at least two codes belonging to mutually exclusive themes. In this case, the themes were *building science content* and *talking about talking.* For instance, the text parts coded as *drawing upon prior knowledge* were nearly always also coded as examples of organizational metadiscourse.

In the examined classrooms, metadiscourse had also other uses and was observed to support both science content and science values (as evidenced by Figure 6.1). Essentially, metadiscourse helps the receiver of the communication "to organise, interpret and evaluate what is being said" (Hyland, 2017, p. 17). In this study, three categories of metadiscourse were identified and used. These are (a) organizational, (b) evaluative (as in Schiffrin, 1980; Tang, 2017) and (c) interpretive metadiscourse (Crismore, Markkanen and Steffensen, 1993). These categories of metadiscourse are listed in Table 6.4.

Table 6.4 Metadiscourse categories and coding labels from the theme *Talking about talking*.

Organizational metadiscourse:	to facilitate understanding of links and connections
Knowledge connectives	connect students' knowledge to conversation
Text connectives	connect one part of a conversation to another
Activity connectives	connect conversation to activities
Evaluative metadiscourse:	to convey scientific values
Attitude markers	signal teacher's stance toward content
Epistemology markers	signal teacher's stance toward truth and epistemology of content
Interpretive metadiscourse:	to help students grasp correct meaning of language and of propositional content
Code glosses	direct students to grasp correct interpretation of words
Interpretive markers	direct students to grasps correct interpretation of content

Overall, content presentation was dialogically supported by *organizational metadiscourse*. This serves the purpose of scaffolding the discourse, making references and connections more explicit and classroom discourse more cohesive. Also, it helps students to better orient themselves throughout the lesson and, on the long run, throughout the development of the curriculum.

Among organizational metadiscourse devices, *knowledge connectives* in particular connect students' prior knowledge to current conversation and facilitates the understanding of links and connections, as in the following examples:

> TEACHER: […]if you designed this structure—<u>remember</u> the creative design, or...the intelligent design of—creation versus evolution—<u>that we have mentioned already</u>.
>
> [CS1-10A-1, lines 216-218]

> <u>TEACHER: As you know</u>, red blood cells carry oxygen.
>
> [CS2-10A-2, line 358]

> <u>TEACHER: We remember</u> the word swallow from Lorenzo, the movie we saw.
>
> [CS3-11A-2b, lines 123-124]

> TEACHER: Because we understand this, <u>we've learnt this</u> about the immune system.
>
> [CS1-10B-3, lines 55-56]

> TEACHER: Evolution is maybe helping us to understand it. (3.0) <u>You remember</u> evolution, right?
>
> [CS3-11A-1b, lines 400-401]

Text connectives help to connect one part of the conversation to another, which also help to capitalize on students' interventions:

> TEACHER: Remember what Lea said about people with O blood group. She said they are…universal donors.
>
> [CS2-10A-2, lines 397-400]

Activity connectives help see the roadmap of the class and prepare students for what is coming or for what they are expected to do:

> TEACHER: We are now going to collect some of your prior knowledge.
>
> [CS1-11-2, line 44-45]

> TEACHER: This is an open question. So, lots of people can say something here.
>
> [Alexandra, 10B-2b, lines 767-768]

> TEACHER: Now it comes the link between what I want to do and what you already know.
>
> [CS1-11-2, lines 253-254]

The presentation of content was also supported by evaluative metadiscourse, such as *attitude markers*, which signal teacher's stance towards content. These were observed playing the role of *alerts* in the science classroom. They can signal importance, difficulty or affect (Tang, 2017, p. 559). I also add oddness, which appears when counterintuitive reasoning is introduced. Here are some examples:

> TEACHER: That's a main distinction.
>
> [CS1-11-1a, line 330]

> TEACHER: […] so, this is another really important point.
>
> [CS1-11-1a, line 342-343]

> TEACHER: If you think about it, this is probably the most important function of the digestive system.
>
> [CS3-11C-1a, lines 377-378]

> TEACHER: […] this is very important but unfortunately, that's something really confusing.
>
> [CS2- 10A-2b, lines 468-469]

> TEACHER: […] lots of things are a little bit weird in the eye. […] So, this is a bit odd actually. […] it's kind of a weird system all around.
>
> [CS1-10A-1, lines 168-212]

> TEACHER: […] isn't that cool? We have a pharmacy inside our large intestine.
>
> [CS3, 11C-1b, lines 585-586]

Attitude markers were also used to signal when students were presented with instructional condensation forms, such as big-pictures or views of the total, as here:

> TEACHER: That's the big picture. That's what we were aiming at. The really important stuff.
>
> [CS1-11-1b, lines 517-518]

Overall, in the examined CLIL classrooms, science content is presented with a notable support of metadiscursive instances, in particular of organizational metadiscourse and attitude markers. Together, these provide the students with a better idea of how the contents they are learning are connected to what they did in the previous lesson, what comes next, what is really important, what is difficult and needs to be treated carefully. Teachers' metadiscourse provides learners with a kind of roadmap that supports the learning of science and with a sort of *cognitive alert system* that informs them when things are getting tricky. The finding on this particular use of metadiscourse contributes to answering RQ2.

This finding resonates with Ifantidou's stance on academic metadiscourse. Ifantidou (2005) rejects the standard view that metadiscourse items are distinct from propositional content and merely peripheral or secondary to constructing and represent ideas (e.g. Hyland, 1998; Vande Kopple, 1997). In this study, metadiscourse is central to the interpretation and construction of scientific understanding. Drawing upon Halliday's (1978) systemic functional linguistics (SFL) perspective, metadiscourse does not only help to convey affective or evaluative stances (*interpersonal function*) or to connect and coordinate parts of conversation (*textual function*). It also helps to construct and represent ideas related to the propositional content (*ideational function*). To sum up, the use of metadiscourse is a linguistic practice that facilitates the presentation of disciplinary content, or, using Ifantidou's words, metadiscourse can contribute "to the effective interpretation of academic discourse" (2005, p. 1350). Results about the use of metadiscourse in CLIL science classrooms also contribute to enriching the research fields concerned with metadiscourse and science education in a second language. So far, metadiscourse has been mainly explored either in regular science classrooms (e.g. Tang, 2017) or in generic CLIL classrooms with a focus on the language (e.g. Nardo, 2017). Only in a recent study, did Msimanga and Erduran (2018) demonstrate teacher's use of metadiscourse in a South African secondary school science classroom with English language learners. The authors found evidence of the use of organitional and attitude markers for mediating conceptual understanding in argumentation activities and concluded that metadiscourse use needs to be further explored and could be learnt and used as a teaching strategy to enhance learning of science by ELLs. The present research study builds on and extends Msimanga and Erduran's results beyond argumentation activities. In the next sections, further uses of metadiscourse are investigated.

6.4 Metadiscourse for Learning What Science is and How Science Works

This section is concerned with analysing how science epistemologies and values are presented in the CLIL science classroom. The focus of this section is on the theme labelled as *building Nature of Science (NOS) understanding*. In particular, this section aims at understanding what dialogue practices promote exposure to science epistemologies. The existing literature about teaching and learning science epistemologies was analysed in section 3.3 in relation to the concept of the Nature of Science (NOS).

As Taber (2017b) points out, the teaching of scientific content, i.e. the products or outcomes of science, needs to be balanced with the teaching of science culture, i.e. the values, the goals and practices of the scientific community. This twofold focus on content and culture was observed in all the examined lessons. Overall, the focus was primarily on content. However frequent explicit references about the processes that generate scientific knowledge and the values system adopted by the scientific community were also present. From the analysis of classroom talk, a theme that refers to this aspect of science learning emerged, which is labelled as *building Nature of Science (NOS) understanding* and addresses both science values (what science is) and science processes (how science works).

The NOS-related ideas extracted from the data address (a) how science knowledge is built, and (b) what values underpin science knowledge. Usually, NOS was spontaneously addressed without planning it. NOS references were favoured by a number of circumstances such as when students (or teachers) challenged scientific authority, when they asked for deeper understanding, when scientific discoveries were explained or when labs activities were commented on, as in the following examples:

> TEACHER: How do you know? [...] Were you just born with knowledge? Do you just know? Like... 'God told me one night'. [...] That's biology, guys. How do we know?
>
> [CS3-11A-1b, lines 7-10]

> SAMUEL: You said that [...] But the book says that [...]
>
> [CS2-10A-1, lines 127-128]

> TEACHER: The doctor in the town began to study him. Because he had a hole in his stomach so the doctor was like 'Can I look?' And so the doctor did. He would observe, as scientists do, he would observe the stomach.
>
> [CS3-11B-2a, 1005-1009]

> TEACHER: [...] going back to our potatoes, a...a decreasing trend doesn't mean a thing if my standard deviations are too big. [...] I really can't draw any scientific conclusion. This is why statistics gives me reliability. Anything else is just... chatting around. It wouldn't be science.
>
> [CS1-11-1b, lines 567-581]

Once emerged, NOS were facilitated by both epistemology markers and attitude markers, as illustrated in Figure 6.3.

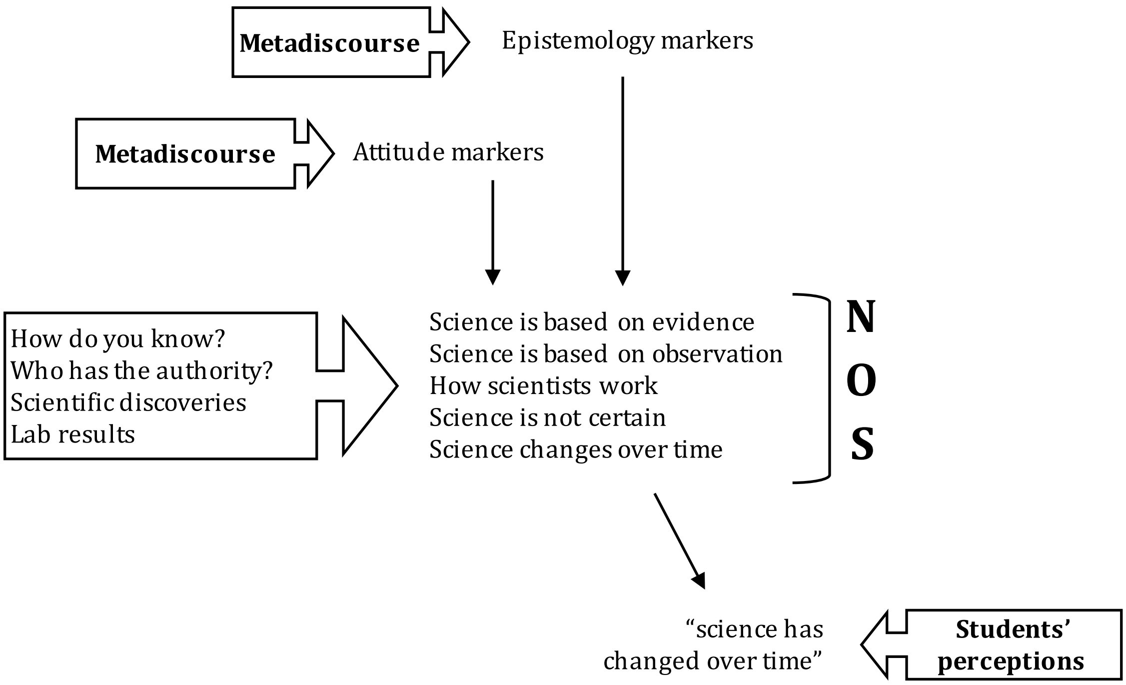

Figure 6.3 Scheme of how *building NOS understanding* and *metatadiscourse* work together in the CLIL classroom to generate opportunities for learning science.

Attitude markers represent a teacher's stance towards scientific content (Tang, 2017; Vande Kopple, 2012). These markers guide students to understand what constitutes acceptable scientific practices. Attitude markers, when used for supporting NOS understanding, provide the learners with a sort of *moral compass* for evaluating science practices, as in the following examples:

> TEACHER: […]that would be really tempting. And believe me, not only you, but many scientists would be tempted to claim the same. Maybe after months and months spent on an experiment. But that wouldn't be fair. That would be bad science.
>
> [CS1-11-1b, lines 548-552]

> TEACHER: You have to decide here if sampling is biased or...random. Remember, in science it's good to be really…random.
>
> [CS1-11-1a, lines 465-466]

In addition, through attitude markers, teachers are able to convey the amazement of scientific endeavour and students learn how science knowledge is continuously re-shaped by new discoveries:

> TEACHER: Today, scientists are discovering that these [gut] bacteria make us who we are. This is crazy stuff!
>
> [CS3-11C-1b, lines 616-617]

> TEACHER: Something amazing is being discovered!
>
> [CS3-11B-2b, line 1793]

These findings build on and expand what Ryder and Leach (2008) found about how teachers transform their personal understanding of science epistemologies into classroom discourse. Ryder and Leach (2008) demonstrated that NOS understanding is promoted by making explicit the links between epistemologies and content and by exemplifying and contextualizing epistemic aspects within content areas. Both these practices were observed. In particular, the presented data show how metadiscourse (attitude and epistemological markers) makes links to science epistemologies and teachers' values visible and explicit ("this is crazy stuff!") and supports exemplifications and conceptualizations of epistemic aspects ("that would be bad science").

As illustrated by Figure 6.3, NOS understanding affects students' perceptions. The analysis of students' perceptions collected through the questionnaire reveals that most students indeed perceive that science is not a fixed body of knowledge, as evidenced by Figure 6.4.

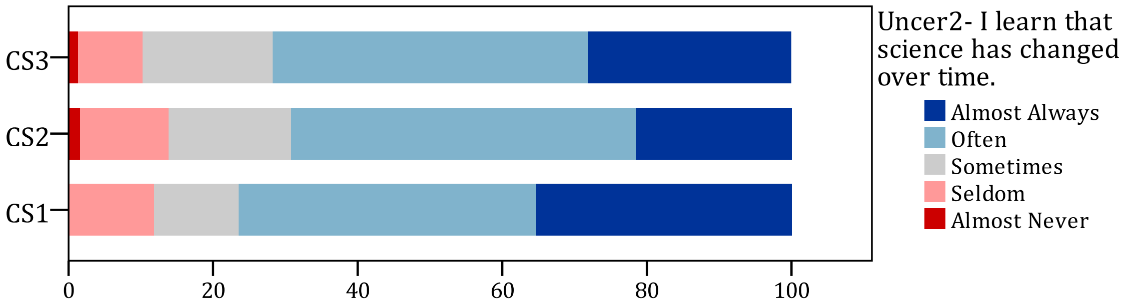

Figure 6.4 Percentages of questionnaire responses across case studies in relation to the item *I learn that science has changed over time* (n = 160).

Regarding *epistemology markers*, these reflect how committed teachers are towards the validity or truth of content material (Tang, 2017; Vande Kopple, 2012). In science education, this usually translates into trying to avoid bias, into evaluating scientific work in terms of evidence, into being open to reconsider old conclusions in the light of new evidence and, in general, into questioning everything (Taber, 2017a). Evidence of these values can be found in the following extracts:

> TEACHER: [...] these are speculations. The honest answer is that no one really knows it.
>
> [CS1-11-3a, lines 287-288]

> TEACHER: [...] this is again another probable answer, though. I can't tell you for sure, but the likelihood is [...]
>
> [CS1-11-3b, lines 611-612]

> TEACHER: But, again, not everybody agrees with this explanation.
>
> [CS3-11A-1b, lines 416-417]

> TEACHER: In science, we do not believe things, we test things.
>
> [CS3-11B-1b, lines 540-541]

As demonstrated by these teachers' statements, in the science classrooms, epistemology markers are important to highlight how "[t]entativeness and uncertainty mark all of science. Nothing is ever completely proven in science, and recognition of this fact is a guiding consideration of the discipline" (Kimball, 1967, p. 112).

To conclude, in the examined CLIL classrooms talk, science epistemologies are built with support of metadiscursive instances, in particular of evaluative metadiscourse, such as attitude and epistemology markers. Through these markers, teachers bring science epistemologies and science values to the CLIL classroom. They help students understand what constitutes acceptable scientific practice and what values underpin scientific knowledge building. The finding on this particular use of metadiscourse contributes to answering RQ2. In addition, how NOS are presented may affect students' ideas about how science is not a fixed knowledge. With these data, it is impossible to establish a cause-effect link between students' perception about NOS and instructional presence of NOS. However, the link is not to be excluded either. In this regard Duff (2000, pp. 109-110) argues that the frequency of exposure determines (a) how much a content is important and (b) the likelihood that it will be noticed and acquired (Duff, 2000, pp. 109-110).

These findings are aligned with what is presented in section 6.3 about the use of metadiscourse for facilitating the presentation of science content. As claimed by Ifantidou (2005), metadiscourse is central and not peripheral in the construction of scientific understanding. This also is important for the provision of scientific epistemologies and values on which science teaching and learning depend (Lemke, 1990).

6.5 Making Content Accessible

As opposed to the previous sections, the focus of this section is not on a particular theme but on the theoretical constructs of *conceptual understanding*, an aspect of which opportunity to learn science in a CLIL classroom is based on. The aim of this section is to examine how conceptual understanding is promoted through the analysis of themes emerged from the classroom transcripts and of other relevant research components.

Teachers have been observed making content "accessible in any number of different ways by anyone" (Alexandra's interview, lines 92-93). In terms of cognitive support, using examples, analogies and similes have been observed intensively in the data. James (CS3) also employed the use of anecdotes and curious facts to support his explanations. Alexandra (CS1) inserted into her speech many direct quotes. An overview of how cognitive access to science knowledge was facilitated is illustrated in Figure 6.3.

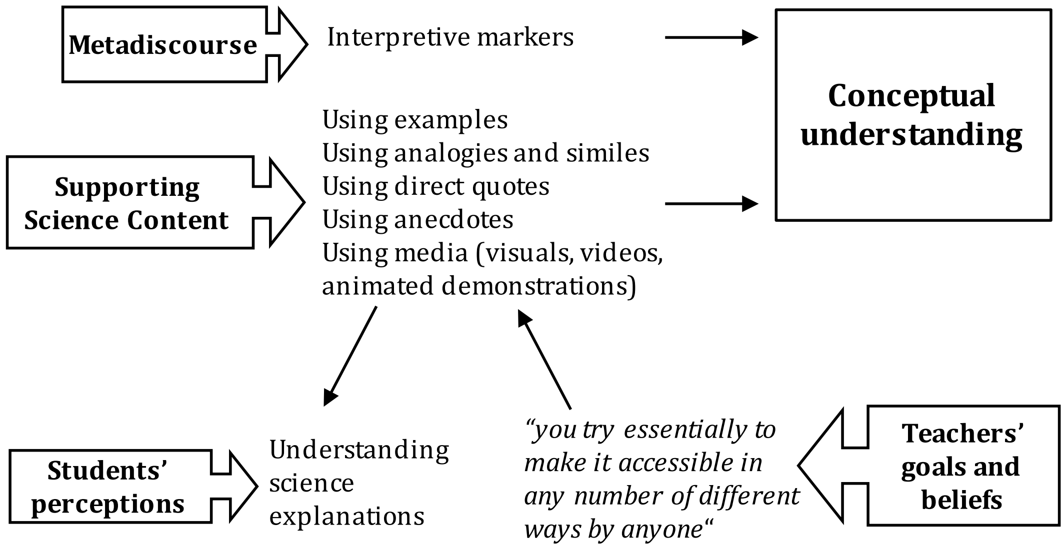

Figure 6.5 Scheme of how *supporting science content* and *metadiscourse* work together with other research components to promote conceptual understanding in the observed CLIL science classrooms.

Analogies and similes serve similar purposes in science learning as they are all "used to make familiar the unfamiliar" (Treagust, Duit, Joslin and Lindauer, 1992, p. 414). Whereas examples are instances from a familiar domain used to illustrate features of a concept, analogies are usually elaborate and extensive comparisons between elements from a familiar and an unfamiliar domain. All three science teachers used examples and analogies quite often. *Examples* were often used to make a point clearer or to understand an idea or an abstract concept. In the following excerpt, Alexandra is explaining the concept of bias applied to sampling using an example:

> TEACHER: If you want to make a list of the fauna of a place, you may visit that place many days until you won't discover any new animal, but you've never been there in the night. Chances are that you're missing all nocturnal animals, right?
>
> [CS1, 11-1a, lines 448-451]

Analogies are essentially similarities (i.e. similes) on a more conceptual level. In line with what Jonāne (2015) found in physics classrooms, also in this study, analogies were used for communicating (abstract) ideas, generating new scientific knowledge, fostering understanding, and helping memorize content, often with the force of imagery, as in the following examples:

> TEACHER: Think of the hair cells [inner ear] like soldiers defending a position...the first lines of soldiers, the ones closer to the enemy, are the ones more at danger of...being killed first.
>
> [CS2, 10B-1, lines 260-263]

> TEACHER: […]the DNA is like a big collection of books, kept in the nucleus, which is kind of a library, from where books cannot be taken out. The ribosome only needs a page or a section of it. You can't put all the books out to the ribosome. It wouldn't know which one to choose. That's probably the reason, evolutionary maybe, why the mRNA system evolved. Because the ribosome only needs the relevant section.
>
> [CS1, 11-4a, lines 212-218]

Anecdotes do not have the cognitive power of analogies, however, as *stories with a point*, they capture students' attention with the force of narration and facilitate memorization. James used them as a *form of evidence* to support his explanations about abstract ideas while capturing students' attention. For instance, for proving the fact that alcohol is a little volatile molecule that is easily absorbed by the human body he told a funny story about a preacher waking up drunk in the morning after being unwillingly exposed to the fumes of distilled alcohol during the prohibitionist era in the U.S. Anecdotes tend to be quite long (short monologues) and require some storytelling skills. It is probably not a case that only James, a native English-speaker, was observed using them.

Direct quoting was another device that supported conceptual understanding. Direct quoting is a sort of speech within speech. In linguistics, direct quotes have been classified as prosodic devices that add layers of voices (Günthner, 1999). In the observed classrooms, they were used by teachers to make the communication both livelier and clearer. As they usually make use of everyday informal language, they also serve the purpose of translating academic language into a simpler and more comprehensible form of language. However, it is their powerful communicative, somehow theatrical, impact that makes them useful devices for conveying abstract ideas or simply for impressing memories, as in the following excerpts (relevant parts are underlined by the researcher):

> So, we take the neurotransmitter away, and the postsynaptic neuron is like <u>"Hi, I'm free to produce an action potential"</u> and it does it.
>
> [CS1- 10A-1, lines 364-367]

> We call them superbugs because they are like "<u>Hi, I'm invincible!"</u>
>
> [CS1- 10A-2, lines 164-165]

A variety of media, such as visuals, videos, animated demonstration were also used during the observations to support conceptual understanding. These are mentioned here, as they serve the purpose of promoting conceptual understanding, however they have not been analysed in this study because they are not strictly part of classroom discourse.

Overall, each science teacher of this study addressed scientific explanations and aimed for conceptual understanding using a personal style that resonated with her/his personality and, for this reason, worked well for her/him. However, CLIL settings may become constrained by linguistic barriers and not only teaching pedagogies, but also the keeping up with your own persona may be challenged. As a result, CLIL teachers have to learn to compromise between what they would do and what they can actually do, which may be limited by students' linguistic shortcomings. Emma, for instance, states the following:

> […] what I sometimes miss, I have to say, is...in German—because, I'm more fluent in German—it's much easier for me to come up with stories, interesting things that just pop up in my mind. […] My lessons are always very structured...
>
> [Emma, lines 222-228]

What Emma is confiding is confirmed in other CLIL studies, where teachers complain about the lack of humour and a reduced personality (Moate, 2011). These are interesting aspects that ultimately influence the opportunity for learning science that would be worth considering in a programme for further research.

6.5.1 'Don't Get Misled!'

Cognitive access to science was observed to be supported also by a particular kind of metadiscourse markers, namely *interpretive markers.*

In this study, *interpretive markers* are metadiscourse markers that direct students to construct the appropriate interpretations as aligned with the scientific thinking. This category of markers is derived from the work by Tang (2017). In the original work by Tang (2017), interpretive markers loosely correspond to what Vande Kopple (2012, p. 39) called "code glosses". However, Vande Kopple's code glosses are essentially meant to "help readers grasp the appropriate meanings of elements in texts" i.e. of words (Vande Kopple, 1985, p. 84). For the purposes of this study, both Tang's interpretive markers *and* Vande Kopple's code glosses are used, with a different meaning: interpretive markers for interpreting extended parts of conversation, code glosses—more linguistic in nature—for correctly interpreting words. The latter is investigated in section 6.6.1.

Interpretive markers help grasp information that is not clearly stated, see logical consequences, catch hidden meanings, or avoid misinterpretations. Often prompted by "That means..." Interpretive markers are based on the use of logic, evidence, content knowledge, analysis and synthesis skills, as in these examples:

> TEACHER: [...] rod cells] share the same connection to the optic nerve. <u>So, that means</u> less sharpness.
>
> [CS1-10A-1b, lines 428-429]

> TEACHER: [...] we have about one-hundred times more bacteria cells than we have human cells. <u>Which means</u> if you count cells, not per mass but just by number of cells, you are more bacteria than you're human.
>
> [CS3-11B-2b, lines 1746-1749]

> TEACHER: [...farm animals] were all given antibiotics, <u>meaning</u> antibiotics were to be found also in products, such as meat... milk and re-consumed by people.
>
> [CS1-10A-2, lines 56-58]

In addition, they also rely on a robust pedagogical knowledge about potential cognitive pitfalls and common instances of counterintuitive reasoning:

> <u>TEACHER: It may seem counterintuitive</u>. <u>The logic would say</u> here 'Hi, a muscle contracts, the ligaments that are attached to that muscle get stretched and the lens flatten, right?' <u>That would be easy</u> to understand. Straightforward. But that's not what happens here.
>
> [CS1-10A-1, lines 3843]

> <u>TEACHER: Don't get misled</u>. Variables are all changeable. [...] <u>The question here is</u> how does the one change and how does the other one change.
>
> [CS1-11-1a, 252-255]

Interpretive markers also help students to see how things are connected and influence each other, as illustrated by the following example:

> <u>TEACHER: [...]if we think about it logically</u>, <u>first of all</u> we have the DNA code and, <u>in other words</u> the instructions of how to make a protein.
>
> [CS1, 11-4a, lines 18-20]

Overall, these facilitating practices can be traced in the teachers' interviews, under the theme *teacher's responsibility*. For instance, Alexandra claims that:

> [...] you try essentially to make it accessible in any number of different ways by anyone, because these are sometimes pretty abstract content.
>
> [Alexandra's interview, lines 91-94]

Similarly, James says that:

> […] the tools that I have…sometimes are visual, videos or even virtual labs and so if I find that students are particularly having trouble I will increase these […]
>
> [James' interview, lines 12-14]

To sum up, conceptual understanding—and thus opportunities for learning—is supported by use of examples, analogies, anecdotes, direct quotes and a variety of media. The choice between these is largely a personal matter and is determined by the teaching styles the teachers feel more comfortable with. Teachers' linguistic competence may influence how they approach explanations. Conceptual understanding is also facilitated by interpretive markers that direct students to grasp the appropriate interpretations and meanings. The findings on this use of classroom instances and interpretive metadiscourse markers contribute to answering RQ2. Moreover, teachers demonstrated an acknowledgement of their responsibility of facilitating the development of conceptual understanding, which contributes to answer RQ3.

6.5.2 'Explanations are Comprehensible to Me'

Opportunity to learn is not a one-way construct, i.e. from teacher to students. In this regard, Lipowsky *et al.* (2009) note that an opportunity to learn must be perceived and utilised by the student in order to be effective. The analysis of the questionnaire's items exploring the extent to which students perceive to understand science explanations reveals that, despite the CLIL setting, the majority of students claim to understand teacher's explanations (Figure 6.6 and Figure 6.7). Moreover, most students claim that difficult concepts are explained in more than one way (Figure 6.8). Perceptions of task difficulty are always considered relative to a personal sense of self-efficacy (Bandura, 1997). According to Schunk Dale (2012), the actual difficulty level is less important than a personal sense of self-efficacy, i.e. a person's beliefs about feeling capable to overcome the challenges and master the task (Bandura, 1977, 1997).

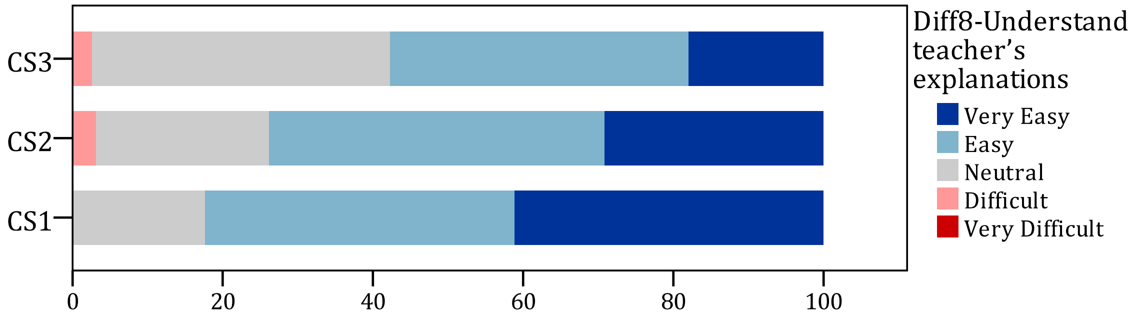

Figure 6.6 Percentages of questionnaire responses across case studies in relation to the item *How difficult it is to understand teacher's explanations* (n = 160).

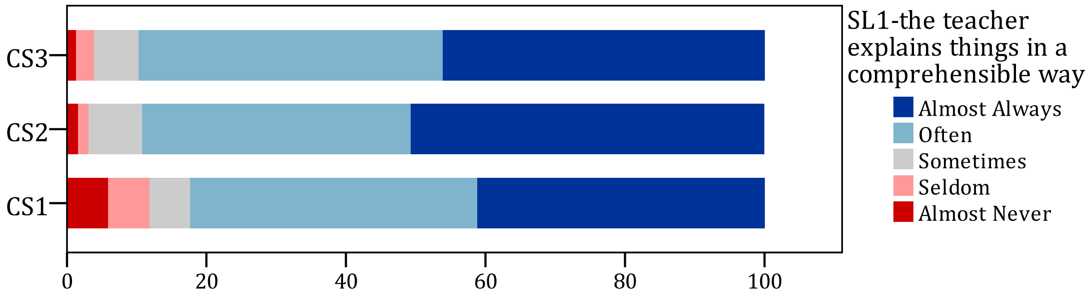

Figure 6.7 Percentages of questionnaire responses across case studies in relation to the item *The teacher explains things in a comprehensible way* (n = 160).

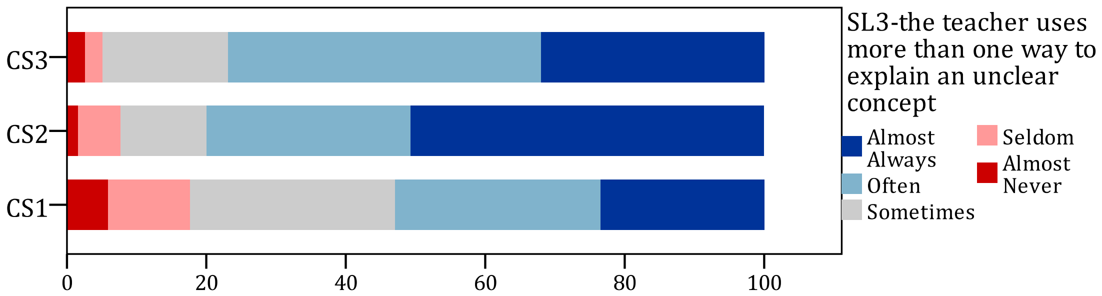

Figure 6.8 Percentages of questionnaire responses across case studies in relation to the item *The teacher uses more than one way to explain an unclear concept* (n = 160).

With this data, it is impossible to relate the positive perceptions of most students about their self-efficacy in understanding content to the teacher's use of supporting strategies and interpretive metadiscourse. Nevertheless, these insights contribute to increasing the robustness of the finding that students generally do not think that a CLIL setting hinders science content comprehension, which—and this has been observed—is permeated with teacher's examples, analogies, interpretive markers that facilitate students' understanding. Overall, this finding contributes to answering RQ4.

Even when explicitly asked if they would understand science more if they were taught in their mother tongue, most students tend to agree that science comprehension would not be better (see Figure 6.9). However, this specific result is less conclusive, in particular as far as CS2 is concerned, and deserves a closer look.

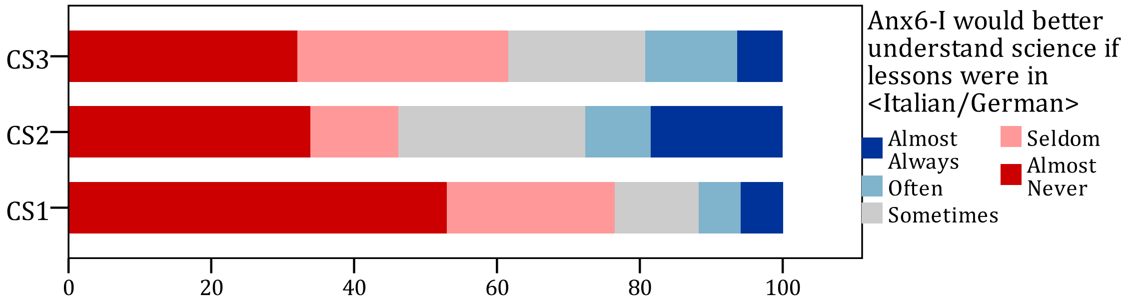

Figure 6.9 Percentages of questionnaire responses across case studies in relation to the item *I would better understand science if lessons were in L1* (n = 160).

In CS2, the majority of students claim that they would, at least sometimes, better understand science if they were taught in German. This result is consistent with the findings of teacher interview when comments on students' attitudes and motivations were explored. Whereas CS1 and CS3 teachers think that their students are quite positive towards learning science through English, Emma (CS2) thinks to share her optimistic beliefs about CLIL's opportunities only with her most senior students, but not with her junior ones:

> I'm sure that bilingual lessons are not easy for many students and many of them would rather be taught in German [...]. Voluntarily choosing to learn biology in English in the 11th year makes a great difference in terms of attitude towards learning. [...] They are probably adult enough to see the opportunities that this kind of learning brings to them. Also, their English language is not a barrier anymore. [...] some of my students frankly, especially the younger ones, they are looking forward so much to the time when they don't have to do biology in English anymore, because they feel they have been left behind.
>
> [Emma, lines 91-208]

By contrast, Alexandra (CS1)—who teaches in a rather selective and academically oriented school—thinks that most of her students find it "cool" to learn science in English (Alexandra's interview, line 35). James (CS3)—who teaches in a school that emphasises languages more than academic curricula—struggles to generate enthusiasm for science in his classrooms. Paradoxically, James' circumstances may end up favouring attitudes towards science learning *because* of the linguistic factor:

> I think that in some cases the students are more excited to have a mother tongue teacher than they are about to learn science.
>
> [James, lines 186-188]

As evidenced by teacher interviews, students' attitudes and motivations about science learning and CLIL may be highly dependent on the context. It appears here that the opportunity to learn science in CLIL classrooms is a complex construct. In this study, it is being investigated only in terms of conceptual understanding, academic language development and participation in classroom discourse, but other factors beyond the scope of this study (e.g. motivational and emotional aspects) may play important roles too.

6.6 Promoting Science Language Development

The focus of this section is on how dialogue practices that promote science language are developed when a CLIL approach is implemented. A general overview of how the development of the register and words of science are facilitated is provided by Figure 6.10.

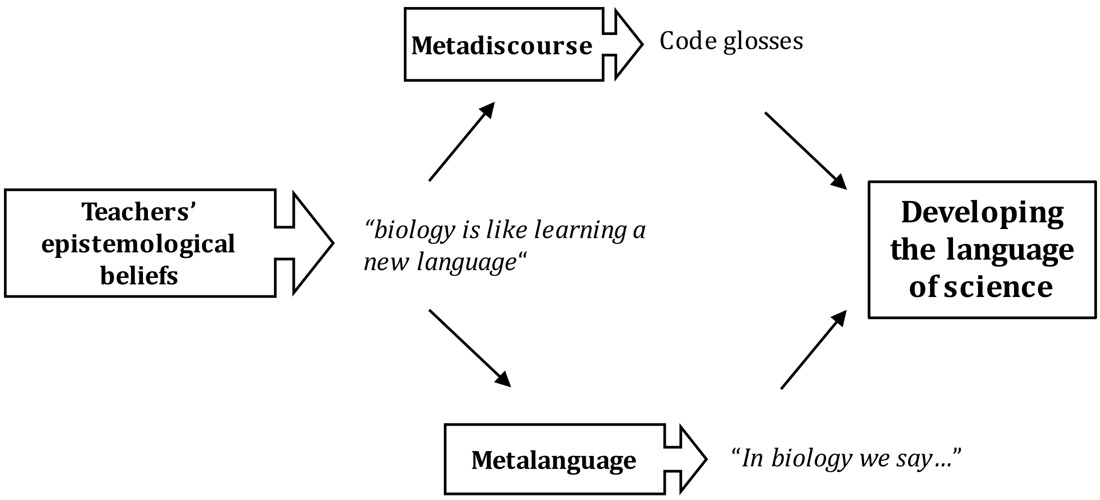

Figure 6.10 Scheme of how science language development is supported by metadiscourse and metalanguage in the CLIL classroom.

In Chapter 5, it was highlighted that teachers' epistemological beliefs about language appear to affect classroom practices. In particular, it was found that when teachers perceive the spoken language as an essential part of the curriculum, students' oral production is richer and more conducive to conceptual understanding (section 5.9). In this section, it is investigated how teachers' goals and beliefs about metalinguistic aspects of science (i.e. academic language) affect opportunities for learning science.

6.6.1 Applying a Gloss to Science Classroom Talk

Code glossing refers to the act of providing additional information to ensure the receiver of the message understands the intended meaning. In other words, code glosses "help readers grasp the appropriate meanings of elements in texts" (Vande Kopple, 1985, p. 84). Paraphrasing Hyland's words ("reader-friendly prose"), code glosses contribute to conveying a *listener-friendly talk* (Hyland, 2007, p. 266). As noted by Hyland, code glosses "reflect the writer's predictions about the reader's knowledge-base or ability to understand text content" (1998, p. 443). In this data, code glosses also reflect a teacher's sensibility, flexibility, and experience in dealing with bilingual learning environments and the ability to prevent linguistic pitfalls and potential misunderstandings. In this sense, code glossing embodies the personal dimension of metadiscourse as it reflects how speakers "use language out of consideration" for their listeners based on their personal "estimation of how best help" their listeners to grasp the meaning of what is being said (Hyland, 2017, p. 17). In other words, code glossing depends on the speaker's sensibility and attitude towards the audience and on personal abilities to bridge the gap with the audience.

In this study, text instances where coded as code glosses when they aimed to promote verbal understanding. By contrast, utterances intended to promote cognitive understanding were coded as *interpretive markers* (e.g. for explaining underpinning/hidden meanings of the text, logical consequences, or conceptual implications, as discussed in section 6.5.1). The differences between code glosses and interpretive markers are summed up in Table 6.5.

Table 6.5 Differences in focus, aim and use of *interpretive markers*, *code glosses* and in *biology we say* instances.

Analytic Code	Focus	Aim	Use
Interpretive marker	Logical connections, appropriate interpretations, correct inferences and conclusions.	Cognitive understanding (underpinning, hidden meanings of text, logical consequences, conceptual implications	Not clearly stated information is followed by conceptual explanations
Code gloss	Meaning of words (often of academic terms)	Verbal understanding (meaning of words, use of words)	Normally, an academic term is rephrased into everyday language
'In biology we say'	Academic form of words	Developing Academic Language	Normally, an everyday language expression is rephrased into academic language

In this data, code glosses were often introduced by phrases like *meaning*, *in other words*, *i.e., namely, it's also known as* and, in general, were used for explaining words whose meaning the teacher feared was not common knowledge. In these cases, reformulations, synonyms or definitions were used to explain the meaning, as in the following examples:

> TEACHER: [...antibiotics] were used not just with sick farm animals but they were given to all animals as a matter of course— <u>meaning</u> anyway, just to prevent them getting sick.
>
> [CS1-10A-2, 52-54]

> TEACHER: <u>Which means</u> my data are a little more spread, a little more scattered around the mean.
>
> [CS1-11-1b, lines 334-335]

Sometimes, teachers were observed using code glosses to explain words that acquire a peculiar meaning depending on the context they are used in, as in:

> TEACHER: [...] the eye sensitivity gradually declines. <u>Declining means here</u> being less strong, not being totally absent.
>
> [CS2-11-1, lines 102-104]

> TEACHER: [..] break apart. <u>Which means</u>...if you have this one molecule of pigment then, after being hit by light, you have maybe two or more smaller molecules.
>
> [CS2-10A-1, lines 241-243]

> TEACHER: So, it's all random. It's random who does, which bacteria cell mutates, or when, there is no rule about it.
>
> [CS1-10B-2a, lines 571-573]

> TEACHER: [...] because if they get bleached—bleach is when all the pigment falls apart, you're dazzled.
>
> [CS1-10A-1, lines 387-389]

> TEACHER: Building blocks <u>means here that</u> a protein is really, physically built of these blocks, the amino acids, one by one, in a row.
>
> [CS1-11-4b, lines 41-43]

In this study, code glosses very often referred to academic language (AL). In these cases, the coding category labelled as *code gloss* may appear close to the category labelled as *in biology we say*. However, these two coding categories were held separated and the *code gloss* label only applied to instances of text whose focus was on the meaning of words and whose purpose was to enhance comprehension.

Only instances of text focused on AL with the purpose of developing AL were actually coded as *in biology we say*, which is examined in section 6.6.2. Table 6.5 provides an overview of the main differences between these coding categories as emerged from this study. The following examples refer to academic language, however they are labelled as code glosses because the teacher's main purpose is to clarify the meaning of the entity they refer to:

> TEACHER: […] a placebo, i.e. a fake drug with no effect whatsoever...like water.
>
> [CS1-11-1a, lines 559-561]

> TEACHER: Chemical means that the matter the food is made of is transformed into something different.
>
> [CS3-11a-2, lines 495-497]

> TEACHER: Digested nutrients are absorbed, that means they cross the wall of the intestine, enter the cells lining the gut and finally enter the blood vessels […].
>
> [CS3-11A-2, lines 769-772]

> TEACHER: […] the virus can be transmitted. Okay? So, it can spread from one person to another.
>
> [CS1-10B-3, lines 193-194]

The practice of providing students with code glosses as disambiguation devices is so deeply ingrained in the classroom talk, that also students have been observed to spontaneously include them in their answers, as in the following excerpt:

> RACHEL: […]My parents are...recessive, which means ho.mo.zy...gous. Uhm…lower case t.
>
> [CS2-10A-1, line 27-28]

The interview with Alexandra (CS1) reveals that her frequent use of code glosses is the result of her reflections on teaching with a CLIL approach. Alexandra feels it is her responsibility to focus on linguistic aspects of the discipline and to try to adapt the classroom talk to her students' needs:

> […] everyone realises to have an obligation to furthering literacy as well.
>
> [Alexandra' interview, lines 122-123]

> [...] to tailor [teaching] better to their understanding and needs and to what might be the best language or just biology language.
>
> [Alexandra's interview, lines 28-29]

To sum up, opportunities for learning are supported by the implementation of code glosses in teachers' metadiscourse, which guide students to grasp the correct meaning of words in general and of academic terms in particular. This practice promotes both science language development and disciplinary understanding. This use of metadiscourse relies on teachers' sensibility and ability to bridge the gap with the audience. The finding on this use of metadiscursive code glosses in the CLIL classroom contributes to answering RQ2. This finding relates to what teachers revealed through their interview—meaning an explicit attention to the language of science—and therefore it also contributes to answering RQ3.

6.6.2 Talking about the Language of Science

Under the theme labelled as *talking about talking*, various aspects of metadiscourse have been analysed for their potential to facilitate both conceptual understanding and science language development. Close to metadiscourse—i.e. the *discourse about discourse*—is the concept of metalanguage—i.e. the *language about language*— which was presented in section 3.6.4. In this study, we refer to metalanguage as "a resource to talk about and reflect on language itself" (Hyland, 2017, p. 17). As the focus of this study is on science learning, the use of metalinguistic devices is investigated for their potential to facilitate opportunities for learning science. In the examined transcripts, metalanguage was mainly used to explicitly talk about and develop the language of science (i.e. academic language). Instances in the transcripts referring to this explicit use of metalanguage were coded as *in biology we say.* As a matter of fact, most of the explicit attention to academic language encountered in the examined data refers to lexical aspects of the language, as in the following examples:

> TEACHER: [...] when the electromagnetic waves are so compressed, so short, or squashed together, we, <u>we say</u> they have a high frequency.
>
> [CS2-11-1, lines 51-53]

> TEACHER: So, that bit <u>is called</u> translation, because now I'm translating the language from the RNA into the protein.
>
> [CS1-11-3b, lines 417-419]

TEACHER: [the viruses] stay in there and then they don't do anything for quite a long time. We say they lie dormant.

[CS1-10B-2, lines 105-107]

TEACHER: [...]We call this blood poisoning, or a very posh word for this is septicaemia.

[CS1-10A-2, lines 292-294]

As evidenced by the previous examples, when recasting in academic language teachers often use the expression “we say”, “we call”. This word choice implies that they refer to a *community of practice* (Wenger, 1998), which is represented by the teachers themselves, their students and the whole community of scientists outside the boundaries of the school, who speak among themselves using the same special language and special words. In this sense, this use of metalanguage has the power to redefine school not as a “self-contained, closed world in which students acquire knowledge to be applied outside, but a part of a broader learning system” (Wenger, 2011, p. 4).

Academic language explicitly emerged in the talk flow when teachers were recasting from conversational language while lecturing or when giving a feedback to a student’s answer. Sometimes, academic language also emerged as a result of an explicit language-related question (in particular, of a *parlance question*). These situations are outlined in Figure 6.11 and a few examples follow below that.

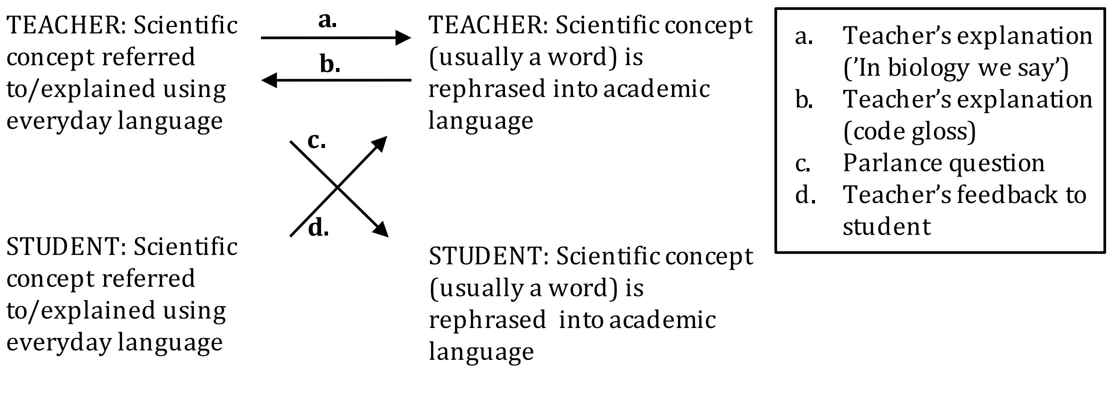

Figure 6.11 Emergence of academic language in the CLIL science classroom dialogue.

Examples of academic language in teacher’s lecturing (coded as *recasting into academic language*]:

TEACHER: […it] qualifies you as the perfect blood donor. (1.0) The universal donor.

[CS2-10A-2b, 461-462]

TEACHER: […] The otoliths react to accelerations, they move by inertia...

[CS2-10B-1, lines 74-75]

TEACHER: […] You probably know that many old people...go deaf. Or they are just hard of hearing. (1.0) Hearing loss is common among old people.

[CS2-10B-1, lines 168-171]

TEACHER: […] And this tells the brain what sound is that, it makes us able to discern sounds.

[CS2-10B-1, lines 165-166]

Examples of references to academic language in *parlance questions*:

TEACHER: The yellow spot...does anybody remember the posh term for it?

[CS1-10A-1, lines 147-148]

TEACHER: Can you give me a term for that? For having a genotype AO or BO?

[CS2-10A-2b, lines 593-594]

TEACHER: […] So, if I translate what you're trying to say into scientific language, what would I say?

[CS1-11-3A, lines 235-236]

Examples of academic language in teacher's feedback (coded as *reformulating*):

MAIA: Maybe the…uhm...the *Sehzellen* <the eye receptors> are good enough.... Uhm, are sensitive enough to get some red, even if they don't...aren't great at red?
TEACHER: Very well. With increasing the distance from the peak wavelength, the eye sensitivity gradually declines.

[CS2-11-1, lines 98-102]

LARA: Maybe the ossicles get... they... *brechen*?<break>
TEACHER: Oh. You mean bones get fragile with age and they easily break, fracture […]

[CS2-10B-1, lines 175-178]

LUISA: There are bad bacteria but also...good bacteria…
TEACHER: Er...they are organism that could be good for the body or bad, that's right. So, they are organisms that don't have to be harmful, or pathogens, they can also be very beneficial.

[CS1-10B-1, lines 11-15]

As evidenced by the last examples, when teachers ask questions or give feedback to students' answers, the focus on academic language can shift from single words to whole sentences. In this sense, students are provided with opportunities to develop and use science language to express science processes and concepts when they are engaged in the dynamics of classroom. Students were also observed reformulating into academic language when answering a teacher's question, as in the following example:

> CHRISTIAN: Um... different pigments absorb different kinds of light. Different…<u>wavelengths of light</u>?

[CS2-11-1, lines 185-186]

Metalanguage, in its broadest sense (cf. Hyland, 2017) truly offers an opportunity not only to talk but also to reflect on language, as in the following excerpt:

> TEACHER: Language is very important here, guys. Correct subject language is essential to understand and learn this stuff. Therefore, I'm now using deliberately, very carefully, the right language.

[CS1-11-3b, lines 232-235]

Here, Alexandra is explicitly urging her students to pay attention to the form of the discipline, not only to the content. This resonates with what she said during her interview:

> […] we realise, especially in biology, that <u>biology is like learning a new language</u> whether you are doing it in your own language or a foreign language. Mmm…there are so <u>many new subject's specific terms</u> that it's almost like acquiring a new vocabulary.

[Alexandra's interview, lines 106-111]

This reasoning is also in line with Alexandra's epistemological beliefs about language, as discussed in section 5.9. It follows that teachers' epistemological beliefs about language do not only affect students' verbal production and cognitive engagement as emerged in Chapter 5, but also how academic language is used in classroom talk and, therefore, how students develop it. This specific finding contributes to answering RQ3.

To conclude, the use of metalanguage allowed the specific language of the discipline to explicitly emerge. This emergence of academic language in a teacher's discourse is at odds with what both Vollmer (2008), and Nikula (2017b) found in the CLIL classrooms they investigated, where academic language remained "implicit or even secret knowledge on the part of subject teachers or pedagogical institutions” (Vollmer, 2008, p. 249). By contrast, in this study, academic language development is indeed supported by the teacher’s use of metalanguage, as recommended by Schleppegrell (2013). Through the dynamics of classroom discourse, students are also provided with opportunities to use science language to express science processes and concepts beyond a mere lexical level. When recasting in academic language, teachers often provide the students with the opportunity to perceive themselves as part of a *community of practice* whose members speak among themselves using the same language. Overall, the findings on this use of metalanguage for developing academic language contribute to answering RQ2.

6.7 Using Redundancy

The focus of this section is on redundancy strategies that promote both conceptual understanding and science language development (Figure 6.12).

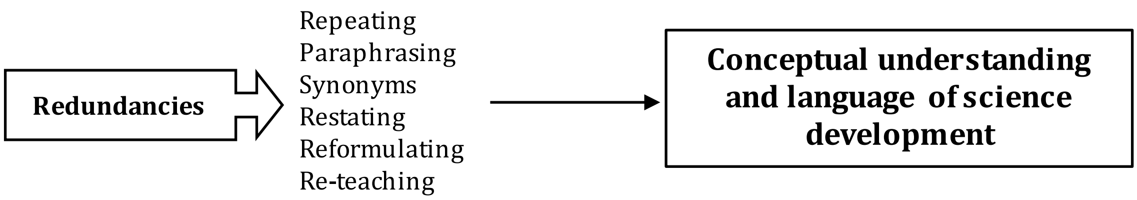

Figure 6.12 Redundancy strategies in the CLIL classroom and their intructional contribution in the CLIL science classroom.

An extensive use of redundancy strategies was a common feature of the classroom talk in all the examined case studies. These comprise paraphrasing, verbatim repetitions, recasting in academic language, the use of synonyms and reiterations. In this study, redundancy strategies were implemented by both teachers and students. Table 6.6 provides an overview of the observed redundancy strategies. The count of each strategy provides an indication about how frequent it was compared to the others.

Table 6.6 Overview of redundancy strategies found in the data set and their functions. The frequencies of occurrence are provided in brackets.

Thematic code		**Main function in the text**
Students' redundancies:		
	Repetitions with hesitation (19)	Thinking aloud Extra time to think
	Repetitions with variation (6)	Refining language Making a stronger point
Teachers' redundancies:		
	Self-repetitions as a rhetoric device (39)	Emphasis
	Reiterations (48)	Emphasis
	Self-paraphrasing while lecturing (154)	Main function: improving understanding Side function: helping memorization, exposing to a richer language/academic language
	Using synonyms (71)	Main function: improving understanding Side function: exposing students to a richer language/academic language.
	Restating students' answers (94)	The teacher repeats verbatim a student's answer for reinforcing new lexical items, for amplifying students' contributions, for marking the importance of a shared building of common knowledge.
	Reformulating students' answers (124)	The teacher recasts a student's answer for developing academic language. Developing the academic genre of *definitions*.
	Rephrasing questions (53)	The teacher phrases or express a question in a different way, mainly to make it clearer. Both a cognitive and a linguistic support.
	Re-teaching	Extended redundancy over multiple subunits of content: the teacher goes back and forth, repeating old content.

6.7.1 When Students Use Redundancies

Students have been observed to unconsciously and spontaneously use repetitions in association with hesitations, signalling that there is some kind of thinking or experimenting in progress and repetitions provide them with extra time to think or to experiment with the foreign language. This kind of self-repetition is usually accompanied by hesitation forms, such as pauses or intonations that sound like questions. This occurrence was coded *repetition with hesitation*:

> KIM: [...]and <u>all the other</u>, like...<u>all the other</u>...<u>all the</u>…<u>other</u> colours, of the visible light, <u>are…are absorbed</u>, except for the green. So...while <u>all the other colours are absorbed</u>, [...]
>
> [CS2-11-1, lines 132-135]

> SELINA: The bonding with <u>hydro...hydro...philic</u> ones?
>
> [CS1-11-2, lines 193-194]

Repetitions with hesitation instances can also be considered as repair communicative strategies (Tarone, 1980). They provide a student with some extra time to further think or to find the correct words. Alternatively, they may be an indication that a student is indeed unable to find the correct word, or to elaborate the concept alone: In these cases, the teacher can appropriately intervene with some kind of help. Barnes (1976, p. 28) labels this kind of talk characterized by “frequent hesitations, rephrasing, false starts and changes of directions” as “exploratory talk”. It “enables the speaker to try out ideas, to hear how they sound, to see what others make of them, to arrange information and ideas into different patterns” (Barnes, 2008, p. 4).

Sometimes students paraphrase themselves. This occurrence is less common than the previous one and was coded as *repetition with variation.* This type of repetitions was generally used in an attempt to refine the language use for academic purposes or to make a stronger point, as in the following excerpt:

> MAIA: Maybe the (2.0) uhm...the *Sehzellen* <eye receptors> are <u>good enough</u>...uhm, are <u>sensitive enough</u> to get some red [...]
>
> [CS2-11-1, lines 98-100]

6.7.2 Repeating for Emphasis

In contrast to the unconscious use of redundancies by students, teachers have been observed to use them purposefully. There is a great variety of purposes for teachers to use this linguistic tool. Some of these purposes are rhetorical in nature, some are conceptual and some are linguistic.

When used with rhetorical purposes, redundancies help to effectively deliver a stronger message (cf. Edwards and Mercer, 1987). Rhetorical redundancies comprise self-repetitions and reiterations. In particular, in their lecturing, teachers use *self-repetitions as a rhetoric device* for adding emphasis to the message.

> TEACHER: [...]and you have different and much more complicated pigments for colour vision. And you have different pigments for colour vision, because you know, colour is the mixture of different...energy, [...]
>
> [CS1-10A-1, lines 307-310]

> TEACHER: [...]An acid that is so powerful it can even melt metal. It has the ability to corrode metal. Imagine that! That's how powerful the acid is in our stomach.
>
> [CS3-11A-2, lines 197-200]

Similarly, teachers sometimes use *reiterations* as a rhetoric device with this purpose.

> TEACHER: [...]because bacteria divide very quickly… again and again and again.
>
> [CS1-10A-2, lines 146-147]

In this excerpt, the repetition of the word "again" helps the students get the concept of how relentlessly bacteria can multiply.

6.7.3 Repeating for Promoting Understanding

Redundancies incorporated in teachers lectures promote both scientific understanding and—as a side effect—language development. These redundancies encompass *self-paraphrasing while lecturing* and *using synonyms*. Their main purpose is to promote understanding. Secondarily, they help memorization and promote language development through the exposure to a richer language and to the language of science. This use of redundancies was particularly abundant in the examined whole data set (see Table 6.6) and in CS1 in particular, where self-paraphrasing appeared as a second nature to Alexandra.

In the following two excerpts, self-paraphrasing enhances the message conveyed:

> TEACHER: [... eye rod cells] are responsible for detecting the brightness of light. They allow us to see in very dim conditions, with very little light. And they respond to very very tiny amounts of light. [...]
>
> [CS1-10A-1, lines 132-135]
>
> TEACHER: [...] So, then the [eye] lens has to get, remember, really fat and pudgy, like very, very convex.
>
> [CS1-10A-1a, lines 22-24]

By paraphrasing herself and using a reiteration ("very, very"), the teacher creates mental images that students can easily visualize and memorize. This use of redundancies strengthens content concepts and helps students to focus on meaningful elements of the content. In addition, it exposes learners to a richer vocabulary ("dim conditions/little light", "fat/pudgy/convex").

Alexandra is also very skilled at using synonyms, as in the following excerpt:

> TEACHER: Outside the body [...] the virus is fragile. [...], *zerbrechlich* <fragile>. It's a handle-with-care type of thing. So, the virus is actually very vulnerable, cannot survive very well once it's outside the... the host. The body.
>
> [CS1-10B-3, lines 176-183]

In this relatively short piece of talk, Alexandra uses quite a few synonyms and also a translation into German for facilitating comprehension of academic lexical items: "fragile/*zerbrechlich*/handle-with-care/vulnerable/cannot survive very well", and again: "the host/the body".

In the following excerpt, Alexandra self-paraphrases herself because she wants her students to avoid misinterpretations:

> TEACHER: [...]Aids is the disease, or the illness you suffer from. HIV is the virus. Lots of people confuse that. Right? So, HIV is the name of the virus and Aids is the name of the disease which you may or may not get when you've been infected with HIV.
>
> [CS1-10B-2, lines 49-52]

By paraphrasing, Alexandra also manages to expose her students to a richer language ("disease", "illness you suffer from", "disease you may or may not get").

6.7.4 Repeating for Broadcasting

In this study, teachers were often observed repeating the propositional content of a student's contribution (see Table 6.6 for the count of instances). Teachers either *restate* (i.e. the teacher repeats verbatim, or nearly verbatim, a student's contribution) or *rephrase* (i.e. the teacher paraphrases what a student said in a more complete or acceptable form). The former kind of redundancy, the *restating of students' answers*, was also termed "echoing" by Zhang (1998, p. 3) who defined it as "the speaker's immediate lexical, syntactic or semantic repetition of the previous speaker's most current utterance(s), sometimes completely and sometimes with some variation". Even though repeating what a speaker just said is conventionally regarded as undesirable in ordinary conversation (Zhang, 1998), Duff (2000) found that it is a common feature in teacher-student interactions.

In Extract 6.1, restating is used by the teacher mainly for amplifying students' contributions, or for "rebroadcasting the students' utterance to reach a wider audience" (O'Connor and Michaels, 1996, p. 74).

Extract 6.1

> TEACHER: [...]What diseases do you remember are caused by bacteria? Nora.

NORA: Uhm... EHEC, food poisoning... blood poisoning.
TEACHER: Yeah, we had EHEC, for example - we had an outbreak here last year. Food poisoning bacteria, like Salmonella. And what was the other one?
NORA: Blood poisoning.
TEACHER: Blood poisoning, yeah. Leon?
LEON: Tetanus
TEACHER: Tetanus, which is blood poisoning... kind of. It's the bacterial name and also the name of the vaccine, the tetanus vaccine. Theo?
THEO: Strep throat?
TEACHER: Strep throat. So, when you have a really bad sore throat, the one that doesn't recover easily, it could be streptococcus, which is a bacterium. Luisa?
LUISA: Uhm, cholera?
TEACHER: Cholera. It's a bad one, from water, yeah.

[CS1-10B-1, lines: 85-102]

In Extract 6.1, restating is used by the teacher as an oral variation of classroom brainstorming: Alexandra (CS1) asks her students what bacterial diseases they remember and instead of writing down the list of suggestions proposed by the students, she simply repeats orally the suggested names and adds some extra information. In this way, Alexandra marks the importance of each single student's contribution in the generation of a shared "common knowledge" (Edwards and Mercer, 1987, p. 2). In addition, restating students' contributions reinforces new/academic lexical items and facilitates their memorization.

6.7.5 Reformulating for Learning the Language of Science

Even more frequent than restating were the instances where the teachers were *reformulating students' answers* (see Table 6.6). These have been labelled as "recasts" by Lyster (1998) and defined by Long (1996, p. 434) as "utterances that rephrase a child's utterance by changing one or more sentence components [...] while still referring to its central meanings". In this study, teachers' reformulations were mainly used to help students develop academic language. In addition, by receiving feedback that is linguistically rich in synonyms, paraphrases and academic terms, learners have better opportunities to expand their linguistic repertoire.

In Extract 6.2, while recasting a student's utterance, the teacher guides the whole class to develop the language of science.

Extract 6.2

TEACHER: [...]What does it mean to be a host? Lea?
LEA: Uhm... in biology it means that uhm a virus... uhm

but also bacteria...
TEACHER: Yeah, all of those.
LEA: Uhm, they kind of use you to live... inside you.
TEACHER: Yeah, you're sort of harbouring them, you're giving them a living space. So, well remembered. Being a host—namely being someone who receives guests, but in biology we use it that way. Your body is a host to the virus, you're hosting the virus [...]Okay. So, the HIV is hosted in the human cells.

[CS1-10B-2, lines 23-36]

In Extract 6.2, the disciplinary term the teacher is focusing on is "host", she confirms the student's answer provided in everyday language—"to live inside you"—and reinforces it by paraphrasing it. This is firstly accomplished using a rich but still conversational language: "harbouring them", "giving them a living space". Then, the teacher points out how the term "host" is used differently in the academic and in the everyday language, and finally, she offers examples of how to use the term correctly both as a noun and as a verb, both in an active and in a passive form. This makes the teacher's intent to develop the use of academic language very clear. In this respect, the use of redundancies can turn out to be a powerful tool for implicitly developing academic language. This finding resonates with what also Chin (2006) found about this redundancy strategy, which she describes as an effective conceptual and linguistic scaffolding and which is particularly beneficial to students with weak language abilities and to ones who have difficulties in verbalizing their thoughts.

Similarly, also in Extract 6.3 and Extract 6.4, Alexandra reformulates a student's answer to a question asked for *checking lexical understanding*.

Extract 6.3

TEACHER: So, visual acuity. First of all, what is visual acuity? Not everyone in this class has the same visual acuity. (2.0) We all have different acuity. Ida.
IDA: *Schärfe*.
TEACHER: Mm, I would rather you explain it in...English.
IDA: You can see things very clear.
TEACHER: Yeah, the clarity, the sharpness of the image. Or...the ability to distinguish between details, right?

[CS1-10A-1b, lines 489-496]

Extract 6.4

TEACHER: And the mode? Maia.
MAIA: It's the number you have the most.
TEACHER: Yeah, it's the most frequent of those numbers

[CS1-11-1b, lines 30-32]

In these extracts, Alexandra's focus is on developing academic language by teaching how to provide definitions while building on students' utterances. Alexandra is here using paraphrases to promote the building of science definitions. Definitions play such an important role in the science classroom that Lemke listed them among the "minor genres" of science (1990, p. 171).

6.7.6 Question Rephrasing

Redundancy strategies were also present in teachers' questions. These *rephrasing questions* were observed to help students better grasp the question, to give some extra time to think about the answer, and to provide the students with some clues or another perspective from which consider the question, as in the following excerpts

> TEACHER: [...] And why do the high-pitched sounds go first? (1.0) What's the reason with that? (2.0) Why are the hair cells here in more danger than the hair cells deep inside the cochlea?
>
> [CS2-10B-1, lines 250-253]

> TEACHER: [...] So, what is needed and what is produced? What other molecules, besides ATP, are produced in the light stage?
>
> [CS2-11-1, 213-214]

In these extracts, the alternative formulations of the teacher's questions provide cognitive scaffolding that help students understand what to focus on in order to successfully answer. Through skillfully paraphrasing, the teacher help students to narrow down their reasoning and get closer to the thinking that is necessary for answering.

Besides providing a cognitive scaffold, teachers also provide linguistic scaffolding by paraphrasing questions, as is illustrated in the following extract:

> TEACHER: [...] how would you describe this particular strand of amino acids? (2.0) What makes a primary structure different from another primary structure. How can I say a particular primary structure is different from another primary structure? (3.0) What can I change about this chain? What can I change to make two different polypeptides?
>
> [CS1-11-2, lines 101-109]

The series of alternative questions that the teacher asks promotes the exposure to a great deal of academic terms that students can use for answering. In addition, the order of the reformulations moves from linguistically more challenging questions ("how would you describe") to a final linguistically less challenging question ("What can I change"), which could potentially be answered with a single word.

6.7.7 Repeating the Teaching

While self-paraphrasing and using synonyms are recurrent practices in Alexandra's classroom and more than occasional practices in Emma's teaching, they are quite rare in James' explanations.

Instead, James implements a lot of *re-teaching* or recursive teaching, meaning that a particular content is first taught/explained to a low degree of depth; then other elements (collateral or linked) are added; subsequently, the former content is explained again (e.g. through recapping, new explanations, media) then other elements (collateral or linked) are further added. Then, again, the first content is recalled and explained. This is all repeated in several cycles, spiralling towards a deeper understanding, a more detailed knowledge, and a more advanced lexical repertoire. Instead of proceeding linearly and covering the different sections of a topic one by one, James goes back again and again to concepts he has already explained, adding new details and more layers of meaning each time.

This approach was consistently observed in James' classroom and the intention that underpins it can be found in his interview:

> […] to continue on one argument multiple times which gives the students the confidence to hear the words, the repetitions, and to start to become engaged in the conversation as opposed to feeling completely left out.
>
> [James' interview, lines 89-92]

This iterative approach to teaching can be considered as an extensive form of redundancy. Through this approach James helps students to organize their thoughts, and arrange them in ways that make sense to them. This also provides his students with multiple opportunities to understand content.

6.7.8 Conclusions on Redundancy Strategies

To conclude, redundancy strategies are powerful tools in the investigated language-sensitive classrooms. They foster opportunities for learning science in many different ways. Essentially, they support conceptual understanding, provide students with extra time to think and promote the development of academic language. As a side benefit, linguistic redundancies also convey stronger and more easily recalled messages. Overall, these findings contribute to answering RQ2.

In particular, in terms of language development, restating students' contributions reinforces academic lexical items and facilitates their memorization. Reformulations of students' utterances expose students to a richer linguistic repertoire and to academically more appropriate forms. Alternative formulations of questions promote the exposure to a richer pool of academic terms that students can use for answering. Overall, repetitions provide learners with greater access to language forms. As observed by Duff (2000), in the long run, these forms are internalized and sustain a more spontaneous linguistic production. The logic behind this is simple: the frequency of exposure determines (a) how much a content is important and (b) the likelihood that it will be noticed and acquired (Duff, 2000, pp. 109-110). From a cognitive second language learning perspective, Skehan (1998) highlights how repetitions of what learners hear make the listening process less dense, leave more time to think and to consolidate what is being learnt. The findings from this study extend to bilingualism what Duff (2000) and Skehan (1998) found in second language acquisition research. They also provide suggestions as to how the teaching of academic language may be integrated in the classroom discourse.

These findings also show how conceptual understanding in CLIL science classroom can benefit from redundancy strategies. In particular, teacher's use of self-paraphrasing enhances communication through stronger messages, helps avoid misunderstandings and guides the focus on meaningful elements. In addition, students are exposed to alternative ways to express the same concept or the same thematic pattern, which promotes the building of meaningful scientific content (Lemke, 1990). By restating students' answers, teachers mark the importance of each student's contribution in the generation of a shared common knowledge. Reformulations of students' utterances promote science literacy development through practicing the micro-genre of definitions. When questions are rephrased and content reformulated, students grasp correct meanings more easily. When content is repeated, students focus more efficiently on what it counts.

6.8 Using Language as Resource

The last theme that emerged from the thematic analysis on the classroom talk is *using language as resource*. This theme deeply reflects the bilingual dimension of CLIL classrooms. Table 6.7 provides an overview of the codes that cluster under this theme with the functions they served most frequently and their presence across case studies. Furthermore, a general overview of how *using language as resource* affects instruction and students' perceptions and of how it relates to teachers' epistemological beliefs is provided by Figure 6.13. The model suggests a pattern of relationship between variables. However, the limited sample size does not allow to draw causality inferences.

Table 6.7 Overview of codes under the theme *using language as resource* found in the data set, their main functions and presence across case studies.

Thematic codes	Function	CS1	CS2	CS3
Student single word in L1	Developing academic language in L2 (through teacher's help) Keeping the conversation (and the thinking) going (repair strategy)	✓	✓	✓
Teacher's single word in L1	Promoting understanding	✓	✓	✓
Providing translation	Developing L1 academic language	✓	✓	✓
Student mixed language	Promoting participation to classroom discourse	✓	✓	
Student answering in L1	Promoting participation to classroom discourse	✓	✓	✓
Teacher's everyday language	Promoting understanding	✓	✓	✓
Asking students for translation	Developing academic language in L1 Reinforcing academic language understanding	✓	✓	✓
Teacher mixed language	Promoting classroom discourse Promoting understanding	✓		
Teacher extended use of L1	Promoting understanding	✓	✓	
Using cognates	Promoting understanding Developing academic language (in L1 and L2)	✓	✓	
Requesting to explain in L1	Checking conceptual understanding	✓	✓	
Inviting to use any language	Checking conceptual understanding. Promoting participation	✓	✓	

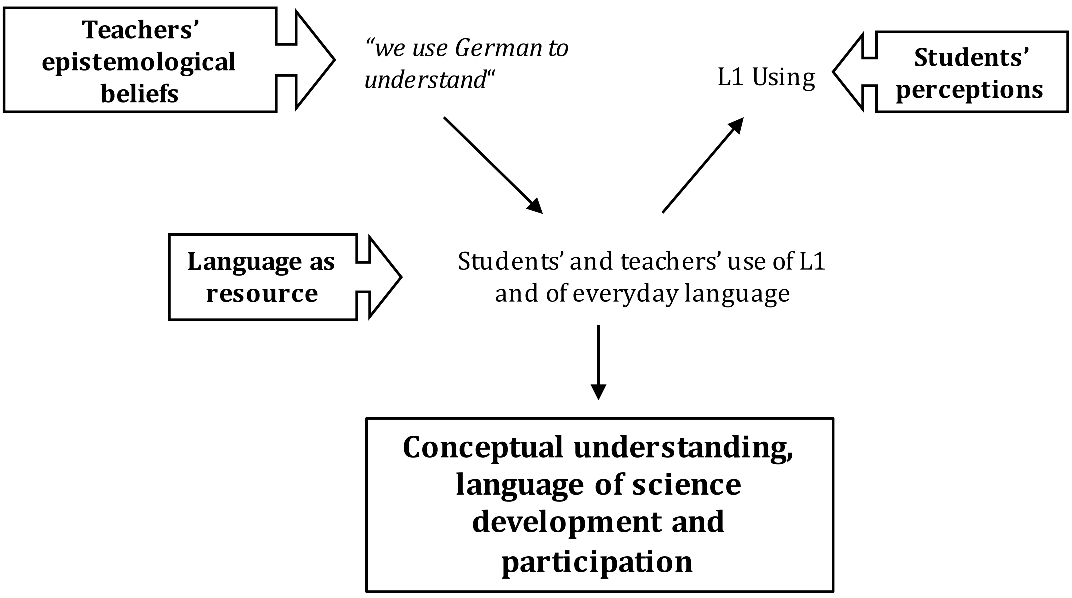

Figure 6.13 Model of how adopting a language-as-resource orientation effects science learning in the CLIL classroom.

6.8.1 Using Everyday Language to Promote Understanding

For interpreting the data of this study, the approach to translanguaging presented by Lin and Lo (2017) is adopted. These authors extend the meaning of translanguaging to also comprise the dichotomy of everyday/academic language. Lin and Lo argue that everyday language is an important resource and that translanguaging also takes place between colloquial and academic speaking.

All three teachers of this study were observed switching between academic and everyday language. In particular, they were observed switching to everyday language through direct quoting. Direct quoting was mentioned in section 6.5 of this chapter as a device for supporting conceptual understanding. It was also noted that this rhetoric device often makes use of everyday informal language. In this study, the shift between casual and academic forms of language has often been observed to occur through the rhetoric device of direct quoting, as in the following examples:

Extract 6.5

TEACHER: […] the right signal in the
nucleus that tells the DNA how and when have a gene
transcribed. It tells the DNA "Right here we need an mRNA".
[CS1-11-3b, 608-610]

Extract 6.6

TEACHER: […] They [antigens] are
just there telling us "Hi there, this is a type A red blood
cell!" Or "Hi, I'm one of Sebastian's liver cells!", or "Hi,
I'm a staph bacterium."
[CS2-10A-2a, lines 377-380]

In these examples, direct quoting serves as a bridge between casual and academic language. The everyday language is "confined" between the quotation marks of teacher's speech, which help students avoid confusion between the two forms of languages. In addition, implementing everyday language in the speech supports students' conceptual understanding. Indeed, in Extract 6.5, the direct quoting translates into vernacular language what academically would sound like "The factor signal indicates which gene is to be transcribed". In Extract 6.6, Emma exemplifies the concept of antigen through imagining *speaking antigens* that use everyday language to specify their biological function.

As in other studies with multilingual students (e.g. Brown and Ryoo, 2008; Brown and Spang, 2008; Lan and de Oliveira, 2019; Moje, 1995), also here, a teacher's ability to flexibly shift between academic language and everyday language and to strategically implement everyday language was observed to promote opportunities for learning science. The findings from this study contribute to answering RQ2, meaning that a "hybrid discourse" (Brown and Spang, 2008, p. 731) facilitates opportunities for learning science. In addition, these data reveal that all the teachers in this study possess an inclusive attitude towards the dichotomy *academic language* versus *everyday language*, meaning that everyday language is not excluded from classroom discourse. This finding also contributes to answering RQ3 research questions addressing teachers' beliefs about language.

6.8.2 Using Cognates as a Linguistic Resource

Languages pairs such as the ones used in the classrooms of this study (i.e. English-German and English-Italian) have many cognates. "Cognates are pairs of words in two different languages that are similar in either spelling or pronunciation and so are easily recognizable in either language" (Pappamihiel and Lynn, 2014, p. 296). Cummins (2009) highlights how cognates represent an example of knowledge *transfer* across languages (see the linguistic interdependence hypothesis Cummins, 1979). Several studies have demonstrated how an effective classroom use of cognates supports and promotes ELLs academic vocabulary development (e.g. García and Nagy, 1993; Nagy, García, Durgunoğlu and Hancin-Bhatt, 1993) and facilitates the recall of words when learning a foreign language (Friel and Kennison, 2001). In particular, because many academic terms have Greco-Roman roots, Corson (1997) argued that many low-frequency academic terms in English are common (i.e. high-frequency) words in Romance languages, such as Italian. For the purposes of this study, this translates into an advantage (or opportunity for learning) in terms of academic language development for native Italian-speakers when it comes to using cognates (Corson, 1997). Cognates can also be found between German and English (Friel and Kennison, 2001).

In this study, the use of cognates is theoretically framed as the use of languages as resources. In this data, cognates were observed to be explicitly used by the students rather than by the teachers. For example, in CS3, while describing the anatomy of the stomach, James was observed to struggle to explain the presence and the function of the so-called *rugae*, i.e. the ridges on the internal surface of the stomach (Extract 6.7).

Extract 6.7

511. TEACHER: [...] These are called *rugae*. *Rugae* help us digest.

[…] These *rugae* are like... what do you call...in the washing machine the...things on the inside of the washing machine. There's a name for them. In the inside of a washing machine…You guys have seen it, there is a drum and then there are these little wings.
Ss: No. [murmuring]
S: But we understand *rugae*...it's like the Italian word for... uhm, wrinkles.
TEACHER: Ah, that's where it comes from the Latin. The wrinkles... *rugae*, that's interesting. (1.0) Anyway, in your washing machine that cleans your clothes there are these... [drawing on the board] they are called agitators […]

[CS3-11C-1a, lines 511-527]

In Extract 6.7, James uses a quite elaborate but interesting analogy to explain the function of an anatomical structure. However, as a native English-speaker he is not aware of the fact that the word *rugae* is a cognate of a common Italian word. In this case, it is a student that points the cognate out (lines 522-523). Somehow, by not sharing the same linguistic resources of his students, James is unable to efficiently use a cognate to help develop his students' academic language. Fortunately, this is done by a student.

Something very similar was observed in CS1, when Alexandra asks the meaning of the word *dormant* (Extract 6.8).

Extract 6.8

TEACHER: […] We say they [viruses in human cells] lie dormant. Dormant. Does anyone know what that means - to be dormant? […]
PAULA: Uhm, to sleep?
TEACHER: Yes!
PAULA: There's the same word in French.
TEACHER: Oh, good. My French isn't so good.

[CS1-10B-2a, lines 106-113]

Again, also in this example, it is a student who points out the existence of "cross-language transfer" (Cummins, 2007, p. 222) between a third language—here French—and English. How easily students pick up on the presence of cognates is also exemplified by Extract 6.9.

Extract 6.9

TEACHER: What is the German word for metabolism? Otto?
OTTO: Uhm... *Metabolismus*?
Ss: [chuckling]

TEACHER: What is *Metabolismus*? What does it mean?
S: *Stoffwechsel*?

[CS2-10B-2b, lines 656-660]

In German, *Metabolismus* is a lower-frequency word than *Stoffwechsel* (Leipzig University, 2011), however it helps students to link English to German. In this sense, the transfer across languages enriches a student's linguistic repertoire. In the last example, it is obvious how cognates help students develop academic language both in L1 and L2 and, concurrently, understand academic content.

Overall, the explicit use of cognates by the teachers was rare in CS1 and CS2 and non-existent in CS3. By contrast, students appeared to easily refer to this strategy, which confirms Cummins' claim that cross-lingual transfer is a normal occurrence in bilingual development (Cummins, 1981b). This finding may help reflect on the importance, in bilingual education, of what Cummins (2007, p. 232) calls "teaching for cross-linguistic transfer", which takes advantage of the interdependence of literacy-related knowledge across languages.

6.8.3 Translanguaging to Promote L2 Academic Language

In the classroom talk transcripts, both students and teachers were observed using L1 in their interactions although with very different purposes.

Students often used isolated words in L1 interspersed in English sentences (*student single word in L1*) while answering and (less frequently) questioning the teacher. This use of L1 signals a linguistic gap, but also the determination to keep the conversation going. This linguistic behaviour is rooted in the fact that students feel comfortable to switch to L1 for single words they are not able to come up with, as in the following examples:

SARAH: We could...*kreuzen*<breed>?
TEACHER: Breed
SARAH: We could breed a black dog with a yellow dog.

[CS2-10A-1, lines 254-256]

KIM: […] So... while all the other colours are absorbed, green is (3.0) is… *widerspiegelt*?
TEACHER: Reflected, yes.

[CS2, 11-1, lines 134-135]

In both excerpts, the students interrupt their answer just after having used a German word in order to wait for the teacher's help. As expected, the teacher is receptive to the student's linguistic gap and provides the translation into English (*providing translation*), which the students can promptly use in the next utterances. This keeps the conversation going, the students use the help provided by the teacher (i.e. the translation), contextually expand their academic lexis in L2 and move on. In this sense, code-switching is a classroom practice that belongs to the Zone of Proximal Development (ZPD) conceptualized by Vygotsky (1978) as a zone in the development of the competences in which a particular task cannot yet be accomplished without the help (i.e. the scaffolding) of an expert. In the examples presented here, the scaffolding is the translation in the target language (L2) that the teacher provides. In terms of content learning, L1 supports the conversation, meaning that the students are still able to answer the teacher and communicate their understanding of the topic in spite of linguistic gaps. Moreover, it can be observed that translanguaging revolves around key terms. This finding is confirmed by Moore and Nikula (2016), who argue that CLIL teachers appear to feel as their responsibility to equip their students with the L2 content-specific vocabulary. According to the data of this study, this is not always true, as exemplified in next section. It appears here that the teacher provides the correct L2 key term only when this is expected or needed by the student.

6.8.4 Translanguaging to Promote Understanding and Participation

In some cases, switching to L1 is done without expecting a translation from the teacher. As in the following excerpt:

> NINA: […] And…translation is like...*eine Übersetzung* <a translation>…Uhm...from mRNA to protein, is that right?
> TEACHER: Yep.
> NINA: And the other one, the... trans... transcription is about DNA... and RNA, is like *kopieren* <to copy>? But not really the same.
> TEACHER: You got it!
>
> [CS1-11-3b, lines 516-521]

In these example, L1 is used more as a resource to complete the communication/thinking than a repair strategy. In a way, this use of L1 is closer to the concept of *translanguaging* presented in section 2.4. This use of L1 is probably less productive in terms of language learning but it is much more productive in terms of content building: it does not interrupt the student's communication and the thinking process of sensemaking. Sensemaking is even facilitated by using L1, as the learner has at her disposal more than one code for organizing her thoughts and translating them into words. This example also highlights how the focus of the teacher is definitely on the meaning rather than on the form, which is consistent with a model of "strong" CLIL (see section 2.8). How sensemaking is facilitated by translanguaging practices implemented by both students and teacher was also illustrated in the previous chapter, section 5.7.2. This finding confirms what Esquinca, Araujo and de la Piedra (2014) found in a two-way-dual-language programme, about translanguaging functioning as a sensemaking tool.

Sometimes students insert more than a word in L1 in their answers and their verbal productions become a mix between L1 and L2 (labelled as *student mixed language*), like in the following examples:

> SELINA: Uhm, the range is uhm... uhm (4.0) it's the difference (1.0) *zwischen dem größten und kleinsten Wert*<between the largest and the smallest value>.
> TEACHER: Yeah, exactly, it's just the difference between the largest and smallest value.
>
> [CS1-11-1b, lines 36-40]

> ANNA: Uhm. It's when the protein... uhm, *aus mehreren Ketten zusammengesetzt ist* <is made of many strands>
> TEACHER: Yeah, so we have more than one polypeptide chain.
>
> [CS1-11-2, lines 221-224]

In these examples, students start in English and end up speaking in German. The teacher confirms the correctness of their answers and provides a reformulation/translation in English. A sub-optimal competence in L2 is not limiting these students' participation in classroom discourse. These results find confirmation in Alexandra' interview:

> I allow kids to use German words, and I help them with the translations as they speak.
>
> [Alexandra's interview, lines 175-176]

Sometimes student answers to a teacher's question are entirely in L1 (*student answering in L1*) because using the English language is too overwhelming:

> MARLENE: Ehm, I don't know how to explain it.
> TEACHER: *Sag es auf Deutsch, wenn Du etwas nicht weißt*. <Say it in German when there is something you do not know.>
> MARLENE: *Die Bakterien sind nicht mehr... empfindlich*. <Bacteria are not sensitive anymore.>
> TEACHER: *Das ist das richtige Wort. Erkläre das*. <That's the right word. Explain it.>
>
> [CS1-10B-1, lines 511-514]

In this example, the teacher, Alexandra, solicits the use of German and supports it by switching to German herself (*teacher mixed language*). Alexandra supports Marlene's participation in classroom discourse and helps the student feel comfortable about having to speak in German. Alexandra needs Marlene to answer her question in order to check the student's conceptual understanding. German is apparently the only way to do it. This resonates with what Alexandra says in her interview:

> […] And…I sometimes use German too when I feel that's necessary to understand. So, we use German to understand. That's something they know and I think it's reassuring […]
>
> [Alexandra's interview, lines 179-182]

Isolated L1 words in a teacher's explanation (*teacher's single word in L1*) also promote conceptual understanding and are usually purposefully used when there is a risk of misunderstanding or when misunderstandings need to be cleared up, as in the following excerpt:

> TEACHER: Ehm... Protein wouldn't be a cell, protein is *Eiweiß* <protein>, that's not the cell, a part of the cell, a component of cells.
>
> [CS1-10B-3, lines 66-68]

The claim that "we use German to understand" finds confirmation also in the fact that both Alexandra and Emma have been observed switching to extended explanations in German (*teacher extended use of L1*) when they realize students may be misinterpreting some concept. Prompting students to use their own home language (*inviting to use any language*) is a practice that both Alexandra and Emma implement to foster participation and that they explain like this:

> If I say 'Explain it in German', then sometimes, some kids would say something… who rarely speak otherwise.
>
> [Alexandra's interview, lines 169-171]

> If it's English I try to give them a chance to say it in German and then let somebody else say it in English.
>
> [Emma's interview, lines 201-203]

Teachers have been also observed interrupting exchanges and explanations for deliberately asking students to recap concepts in German (*requesting to explain in L1*):

> TEACHER: *Kann jemand das auf Deutsch erklären, bitte?* <Can somebody explain this to me in German, please?>
>
> [CS2, 10B-1, lines 99-100]

This kind of request is motivated by the need to get feedback on what students are or are not understanding as is explained by Emma in her interview:

> I have to... actively look for a feedback and I often ask them to explain in German what we just did in English. That's good for the whole classroom too.
>
> [Emma's interview, lines 170-173]

Overall, L1 use in CLIL upper secondary classroom promotes conceptual understanding, and thus, facilitates opportunities for learning science. In addition, these data reveal that Alexandra and Emma possess an orientation of language-as-resource. In other words, L1 is not excluded from their classroom discourse. When Alexandra does not translate into English what her students say in German, she is giving the implicit message that there is not a *correct* language to be used, but rather a pool of languages that students are welcomed to bring to the science discourse. This aspect resonates with the thought of scholars who criticise prescriptive ideologies which dictate that there are appropriate linguistic practices while stigmatizing others (e.g. Cummins, 2000; Flores and Rosa, 2015). This finding also contributes to answering RQ3 research questions addressing teachers' beliefs about language.

6.8.5 Using Translations to Promote L1 Academic Language Development

The use of L1 in the classroom is not always a response to a student's lack of language competences. Sometimes L1 use is explicitly requested by the teacher with the sole purpose of promoting L1 academic language development, as in the following examples:

> TEACHER: What is the German word for metabolism?
>
> [CS2, 10B-2b, line 656]

> TEACHER: So, are you wondering what the cones are in German?
> S: *Kegel*<cone—as geometrical shape>?
> TEACHER: Uhm, that would be too easy…*Zapfen*<conifer cone>.
> Ss: [Chuckling]
> TEACHER: Yeah, German scholars love botany, apparently.
>
> [CS1,10A-1b, lines 449-455]

In these two extracts, an academic term had been mentioned earlier. Now, the teachers deliberately move the classroom focus onto a linguistic issue: the translation into L1 of that academic term (*asking students for translation*). In these cases, both teachers are not aiming to improve linguistic understanding because the students are already familiar with the scientific word. Instead, the two teachers are interested in developing academic terms *also* in L1. This is confirmed by Emma when talking about her teaching aims:

> I have to admit that I often think about
> my own teaching that I'm teaching biology *in* English.
> But that's not my job. I have to teach *bilingual*
> biology, in the sense that <u>I also have to give my students
> German terms, and switch language and use mediation
> and something like that.</u>
>
> [Emma's interview, lines 150-155]

Occasionally, a translation into L1 of an academic term was requested as a way to explain the term. This happened in particular for abstract concepts, such as in the following example:

> TEACHER: So, bias is...how can we translate it? What is bias,
> in German? Nina.
> NINA: *Fehler* <mistake>?
> TEACHER: Mmm, that would be error. It's actually linked to
> it, but in a quite...subtle way. Bias... or maybe its adjective,
> biased, or unbiased. Maia?
> MAIA: *Voreingenommen <prejudiced>*?
>
> [CS1, 11-1, lines 423-429]

In this extract, Alexandra asks what bias is in German because she guesses that the translation of the term is likely to provide the meaning of it. In this case, Alexandra is using L1 as a resource for conceptual understanding. The teacher's knowledge about how German language functions (i.e. compound words) is giving this CLIL classroom a chance to better grasp an abstract science concept.

6.8.6 Adopting a Translanguaging Approach

Providing students with L1 academic terms has also practical implications. In the 12th year (final year before *Abitur*, the leaving state exam) German students go back studying all their subjects in their mother tongue, which is the language they are going to be assessed in during the leaving state exam. In both Emma's and Alexandra's classes, reverting to German in the last year of instruction does not seem to be a problem. In particular, Emma confirms the interdependence hypothesis of Cummins (1979) which states that abilities acquired through L2 are accessible for L1 usage as well:

> Going back to German at that stage is not a big deal for them, after all
> German is their mother tongue.
>
> [Emma's interview, lines 64-69]

By contrast, in James' classrooms, where neither students nor teacher are used to mixing languages (see Table 6.7) and students continue to use L2 for learning biology until the exam eve, students have difficulties to revert to Italian:

> What I found is that my CLIL students they can tell me the words in English, they're pretty good. But they can't tell me in Italian.
>
> [James' interview, lines 274-276]

These data reveal that it is not possible to successfully revert to L1 in CLIL science classrooms unless (a) some habits of mixing languages are part of the classroom culture (as in CS1 and CS2) and (b) students have some accommodation time for getting back to L1 before the exams. In this regard, Moore and Nikula (2016, p. 222) note that:

> If learners in a bilingual class are learning new content through an L2, we would be tempted to argue that it is the bilingual teacher's responsibility to ensure that they are equipped to deal with the concept in either/both language(s).

This aspect has not received much attention by research, even though Gil, Garau and Noguera (2012) report gaps in learners' L1 specialised terminology, which confirms what James also noted. In this study, the issue of gaps in students' L1 lexis seems not to exist in the two case studies where translanguaging practices are a norm.

According to the findings emerging from the thematic analysis, code-switching—meaning the simple shift between two languages—is present in James' classrooms. What *is* lacking however, is translanguaging, meaning more complex processes that involve the flexible and strategic use of multiple languages (García, 2009). The lack of presence of translanguaging practices in James' classrooms is confirmed by students' perceptions collected through the questionnaire. Most of James' students perceive that words are almost never or only seldom translated into their mother tongue (Figure 6.14) and that the teacher almost never or only seldom uses students' first language to facilitate conceptual understanding (Figure 6.15). Furthermore, only the minority of James' students think they can use Italian when they need to (Figure 6.16). These findings contribute to answering RQ4, addressing students' perception about classroom practices. It may be speculated that these results reflect the fact that James is a native English-speaker (cf. García-Nevarez, Stafford and Arias, 2005; Kraemer, 2006). Overall, this data suggests that in James' classrooms some real opportunities to access science and therefore to learn science are lost because the students' first language is not capitalized on in the classroom practice.

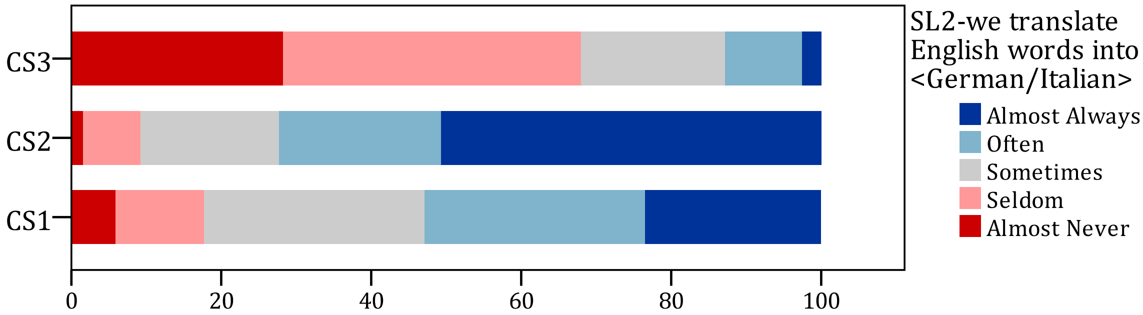

Figure 6.14 Percentages of questionnaire responses across case studies in relation to the item *We translate English words into <German/Italian>* (n = 160).

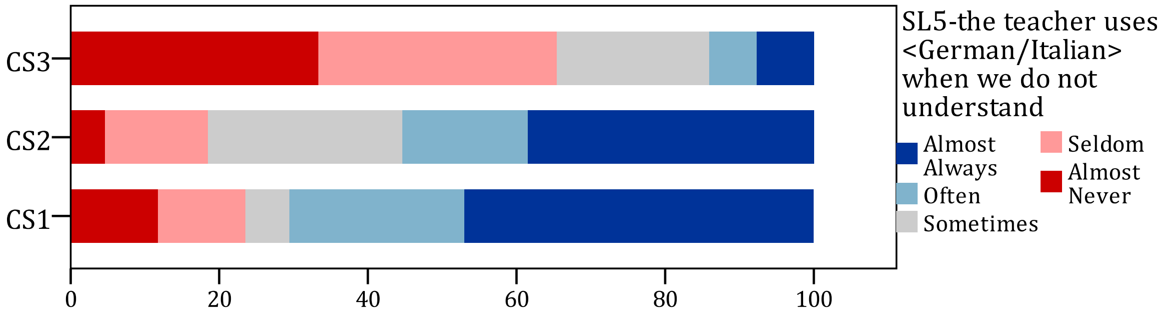

Figure 6.15 Percentages of questionnaire responses across case studies in relation to the item *The teacher uses <German/Italian> when we do not understand* (n = 160).

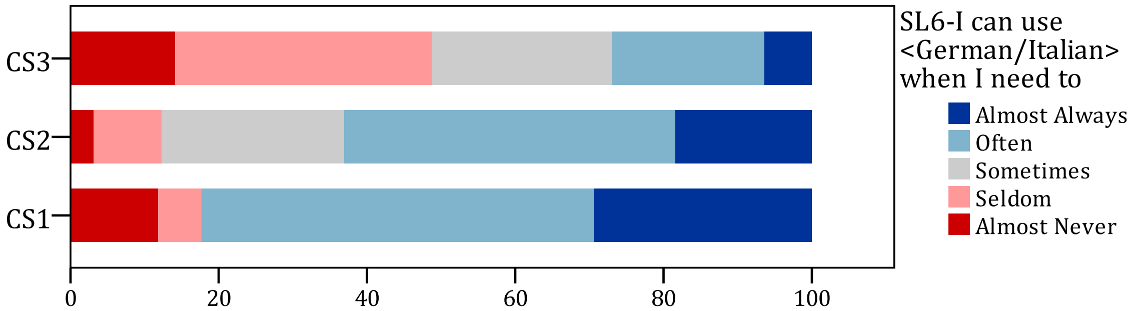

Figure 6.16 Percentages of questionnaire responses across case studies in relation to the item *I can use <German/Italian> when I need to* (n = 160).

When questionnaire responses are cross-checked with results from thematic analysis on classroom discourse (outlined in Table 6.7) and with results from the thematic analysis of teacher interviews, some commonalities across cases emerge. In particular, translanguaging practices appear to be linked to teachers' epistemological beliefs.

In particular, results about the theme using *language as resource* resonate with the theme *language use* emerging from the thematic analysis conducted on teacher interviews. Both Alexandra and Emma value the bilingual dimension of language as a resource (as evidenced in their interviews, see previous chapter, section 5.9), which James seems unable to acknowledge. The effect of this epistemological belief about translanguaging is reflected in the student questionnaires responses, where most of James' students reveal that translanguaging practices are not common in their classrooms (Figure 6.14, Figure 6.15, and Figure 6.16). On the contrary, when teachers (as Alexandra and Emma) acknowledge the bilingual dimension of language, translanguaging practices are perceived and used by students as resources to access science.

To conclude, *using language as resource* is indeed effected by a teacher's epistemological beliefs and pedagogical goals, as illustrated in Figure 6.10 at the beginning of this section. This finding contributes to answering RQ3.

6.8.7 Conclusions on Code-Switching and Translanguaging Practices

Through the thematic analysis of classroom discourse it emerges that the CLIL science classroom is a place where languages are used as resources for socially building science knowledge. In particular, isolated words in L1 signal both a linguistic gap and the determination to keep the conversation going for developing content knowledge. A more extensive use of L1 by students indicates that the participation in classroom discourse is not dependent on only one linguistic code but on all the linguistic resources the students have at their disposal. Data demonstrate that students' use of L1 promotes participation in classroom discourse, the development of conceptual understanding and of L1 academic language. Teacher's use of L1 promotes both conceptual and linguistic understanding and offers opportunities for developing L1 science language. In addition, teacher's use of L1 influence students' linguistic identities (cf. Brown and Spang, 2008) and promotes ideologies of inclusion (cf. Lemmi *et al.*, 2019).

The results obtained through the triangulation of observational data with data collected through teacher interviews indicate that an educational approach that promotes translanguaging practices facilitates the transfer of content knowledge from one language to another. This finding is confirmed in a growing number of studies conducted by scholars who explore language as a tool for learning disciplinary content, who consider translanguaging as a positive pedagogical tool for appropriating disciplinary meanings (e.g. Canagarajah, 2011; Creese and Blackledge, 2010; Garza, 2017) and who are oriented towards a conceptualization of language as a resource (e.g. Moschkovich, 2002; Ní Ríordáin, 2018; Planas and Setati-Phakeng, 2014) that needs to be understood, valued and used as an asset.

In CLIL-specific research, translanguaging has received little research attention so far (Nikula, 2017a), as was examined in section 2.4. For instance, in the reference work about CLIL discourse by Dalton-Puffer (2007)—often cited in the findings chapter of this thesis—neither translanguaging nor code-switching are considered. However, some studies concerned with the instructional use of L1 in

CLIL classrooms have recently started to emerge (e.g. Lasagabaster, 2013; Lin and Lo, 2017; Moore and Nikula, 2016). Even though most of these studies adopt views that see "L1 as a problem" (Nikula, 2017a, p. 118), they are beginning to be counterbalanced by views of language that advocate multilingual resources use in CLIL settings (e.g. Moore and Dooly, 2010; Moore, Evnitskaya and Ramos, 2016). This is the first study in a CLIL context that explicitly adopts a language-as-resource orientation. It is also the first study, in science education, that adopts a language-as-resource framework for investigating classroom discourse. As mentioned before, Lemmi *et al.*'s study (Lemmi *et al.*, 2019) has adopted such a framework for analysing science teachers' ideologies about language by using data collected through focus groups.

In this study, the implementation of translanguaging practices resonates with a teacher's epistemological beliefs about language as claimed thorough interviews. Also, it was found that a teacher's attitude to using L1 does not fully correspond to the same teacher's attitude to switching between academic and everyday language. All three teachers implement a hybrid discourse (everyday language and academic language), but only Alexandra and Emma showed an inclusive attitude towards using L1. This may indicate that beliefs about these two language-related aspects are distinct, meaning that the adoption of an inclusive approach towards a hybrid discourse does not necessarily mean also favouring translanguaging practices when it comes to students' L1 use. Considering how strongly language affects science learning, science teachers in bilingual environments should become aware of their language beliefs and act responsibly. This aspect has important teaching implications and represents an interesting direction for future research. In this study, only James did not embrace translanguaging practices, which could be explained by him being an English native-speaker (cf. Kraemer, 2006). In this regard, García-Nevarez *et al.* (2005) found that Latino bilingual teachers are more supportive of using Spanish in bilingual US classrooms than monolingual native English-speaking teachers, who are less familiar with their students' first language. Interestingly, James' approach to translanguaging was mirrored by his students. The appropriation of a teacher's language practices by his or her students has already been observed in other studies in science education with minority-language students and was explained as the appropriation of a discursive identity (e.g. Brown, 2004; Brown and Spang, 2008). This aspect carries significant implications for science CLIL classrooms and could also represent an interesting direction for future research.

Overall, these findings on the use of code-switching and translanguaging practices contribute to answering RQ1, RQ2, RQ3 and RQ4. In addition, they carry significant implication for science teaching in CLIL settings.

6.9 Conclusions

A few key findings emerged from the thematic analysis of classroom discourse that are relevant for investigating opportunities for learning science in a CLIL setting. These are summarized here with some implications for teaching science in a CLIL setting:

- Conceptual understanding in the CLIL science classroom is promoted by the use of metadiscourse. In particular, organizational metadiscourse help students to better orient themselves throughout the lessons and throughout the development of the curriculum and to make connections more explicit. Attitude markers signal importance or difficulty and interpretive markers help students to grasp the appropriate interpretations and meanings of science content. Epistemology markers have been observed to support the transmission of science values and epistemologies. In a CLIL classroom, metadiscourse also allows teachers to be responsive to students' language and to build from that. Overall, metadiscourse proved to be a useful tool for assisting students and teachers to develop conceptual understanding. This finding builds on and expands what Msimanga and Erduran (2018) recently found about argumentation-based teaching in multilingual South African science classrooms where English is the main language of instruction. Msimanga and Erduran found that metadiscourse helps teachers (a) make their teaching purposes clear, (b) make connections, (c) call attention to important items. This study overall confirms Msimanga's findings. In addition, it was found that metadiscourse guides understanding through interpretive markers and supports the building of science language through code glosses. The present study is the first to address metadiscourse in bilingual science classrooms with the purpose of investigating science understanding beyond classrooms argumentations. Science teacher education could benefit from these findings and include explicit attention to metadiscourse in interventions aimed to empower teachers for effective science teaching in CLIL classrooms.
- In the CLIL science classrooms of this study, conceptual understanding is also promoted by an extensive use of examples, analogies, anecdotes and direct quotes, which help both memorization and understanding processes. Each science teacher seems to possess a personal style for explaining scientific

concepts that favour one strategy or another, and that resonates with her or his personality and that, for this reason, works well with her or him. However, CLIL settings may be constrained by linguistic barriers and teaching pedagogies may result in being challenged by this. Ideally, teachers should not abdicate what are their most natural ways to explain science for the sake of language. Instead, as in the examples of this study, they could scaffold them with other teaching strategies (e.g. metadiscourse, linguistic redundancies, code-switching).

- Redundancy strategies such as paraphrases, synonyms, rephrasing of questions and re-teaching promote both conceptual understanding and content memorization. The same redundancy strategies also promote the development of academic language and of science literacy (e.g. micro-genre of definitions). These findings provide support for and extend to bilingualism what Duff (2000) and Skehan (1998) found in studies in second language acquisition. Moreover, when these strategies are enacted students perceive that their conceptual understanding is not limited by linguistic barriers, which is suggested by the fact that the majority of the students of this study claim to understand teacher's explanations. Linguistic redundancy could be considered as a desirable practice to scaffold teaching in CLIL. Therefore, CLIL teacher education could benefit from this finding and plan to include an effective use of linguistic redundancies into interventions aimed to prepare teachers for effective science teaching while adopting a CLIL approach.
- Translanguaging practices have been observed to create a discursive space where students can verbally elaborate their thoughts and overcome conceptual gaps. When translanguaging practices are promoted, more students manage to participate in classroom discourse, to have their answers checked and to dialogically build meanings. As this study included teachers with different epistemological beliefs about language and different approaches to translanguaging, it was possible to get some insight into how different approaches affect classroom practices and opportunities for learning science. In particular, comparing how native and non-native teachers in the language of instruction respond to the linguistic needs of CLIL learners (cf. García-Nevarez *et al.*, 2005) proved to be an effective strategy to examine translanguaging practices and their potential for conceptual understanding. In this study, translanguaging practices were supported by a teacher's epistemological belief that both L2 *and* L1 are a means for understanding and participating in classroom discourse. In addition, translanguaging practices were observed to promote the development of L1 academic language.

Translanguaging is one aspect in CLIL research that has received relatively little research attention (Nikula, 2017a). This is the first study to investigate translanguaging for supporting content (science) learning in a CLIL context. Translanguaging practices resulted to have a great impact on opportunities for learning science in upper secondary CLIL classrooms. However, these findings on translanguaging practices are not generalizable because of the methodological limitation of the study. Therefore, it would be advisable to investigate on a larger scale how teachers' conceptualization of language use influences conceptual understanding in CLIL science classrooms. Studies in this direction would have a great instructional impact.

Overall, the findings reported in this chapter refer to everyday teaching practices and teaching attitudes that, if routinely implemented, can make a difference in terms of how bilingual students access science knowledge. However, the hidden message is *not* that the practices reported in this study are the *correct* ones. These practices were significant in the observed context and may help educators by providing them with useful insights into how classroom discourse supports and facilitates science learning in CLIL environments. Ultimately, the author believes that practitioners can only improve their teaching practices by going through a process of personal observation and reflection. The findings presented here can guide and occasionally illuminate this personal discovery travel. In this sense, the findings obtained from this study could be presented in in-service science teachers' training as a source of reflection.

An overview of the findings produced in this chapter is provided by Table 6.8, which also shows how these findings are related to the research questions.

Table 6.8 Overview of findings from Chapter 6 in relation to research questions.

Research questions	Key component	Findings from Chapter 6
RQ2 - What **teaching discourse practices** facilitate **opportunities for learning science** in three case studies involving German and Italian upper secondary level science classrooms when a CLIL approach is implemented?	Conceptual understanding	- Use of **examples, analogies, direct quotes and anecdotes.** - Inclusion of **NOS** in teachers' explanations (science values and epistemologies). NOS transmission is promoted by students challenging the scientific authority, asking for deeper understanding, commenting on experiments (all require verbal production) and the recollection of scientific discoveries. Epistemological markers support NOS transmission. - Teacher's **organisational metadiscourse** (e.g. knowledge, activity and text connectives) - Teacher's **attitude markers** (e.g. importance, difficulty, affect, weirdness of counterintuitive reasoning) - Teacher'*s* **interpretive markers** (metadiscourse) for grasping appropriate interpretations and meanings - **Redundancies** (using paraphrases, synonyms and rephrasing of questions) promote understanding and memorization - **Re-teaching** promotes content understanding - **Translanguaging** practices create a discursive space where students can verbally elaborate their thoughts and overcome conceptual gaps (also relevant for RQ1)
	Science language development	- **Code glosses** in the teacher's metadiscourse for guiding students to grasp the correct meaning of words in general and of academic terms in particular. - **Metalanguage** for explicitly speaking and developing academic language and for perceiving themselves as part of a community of practice. - **Linguistic redundancies** (paraphrases, synonyms, reformulations of students' answers) promote academic language and science literacy (definitions) development. Re-teaching promotes academic language development. - **Translanguaging** practices promote the development of academic language and classroom participation (also relevant for RQ1).
RQ3 - What are **teachers' goals and epistemological beliefs** about teaching science through a CLIL approach and how do they affect classroom practice?	Teachers' goals and epistemological beliefs	- Teachers feel their responsibility to facilitate conceptual understanding by any means. - Teachers' goals and epistemological beliefs affect teachers' meta talk (use of code glosses) and metalanguage (e.g. Alexandra feels as her responsibility to focus on linguistic aspects of the discipline and to try to adapt the classroom talk to her students' needs) - Teachers' epistemological beliefs about language affect how academic language is used in the classroom talk and how students develop it. - Teachers' goals and epistemological beliefs affect teachers' approach to translanguaging practices (use of L1 for understanding, participating and for developing academic language)
RQ4 - What are **students' perceptions** of learning science through a CLIL approach?	Students' perceptions	- Most students have acquired the fundamental NOS idea that science changes over time. - The majority of students claim to understand teacher's explanations and acknowledge teachers' flexibility in explaining. - When translanguaging practices are present, these are associated with the students' positive perception that using L1 in class both facilitates access to disciplinary content and participation in classroom discourse.

Chapter 7 Conclusions, Recommendations and Future Research

What if, as a field, we worked to construct a different narrative? One that conceptualizes the heterogeneity of human cultural practices as fundamental to learning, not as a problem to be solved but as foundational in conceptualizing learning and in designing learning environments. (Rosebery et al., 2010, p. 323)

7.1 Introduction

This chapter provides a summary of the thesis from the initial review of the literature to the findings and answering of the research questions. The key findings emerging from this research study are brought together and presented in a critical re-examination of their contribution to the fields of science education research in bilingual contexts and to European CLIL research. Recommendations for enhancing opportunities for learning science in CLIL settings are made. Finally, possible directions for future research to further investigate science learning in CLIL environments are considered.

7.2 Overview of Research Problem and Research Purpose

This research study investigated the influence of a CLIL approach on science learning at upper secondary level in European contexts. A systematic literature review revealed that the main focus of the current research into CLIL—primarily conducted by language experts—has been either on language (both qualitative and quantitative studies) or on validating CLIL as a pedagogical approach (mostly quantitative studies). In addition, even when looking at content, research on CLIL has tended to adopt a language learning orientation in design, analytical tools and theoretical orientation (e.g. Evnitskaya and Morton, 2011) and has so far produced inconclusive outcomes (as reviewed by Bonnet and Dalton-Puffer, 2013). As a result, very little is known about the effects of CLIL on content knowledge in general (Dalton-Puffer, 2011; Heine, 2010) and even less on science learning in particular.

Leading on from the above, it is apparent that there is a need to improve the understanding of the effects of a CLIL approach on the learning of science. In particular, I identified a need for a better understanding of science classroom discourse in CLIL settings, in light of the emphasis placed on language and on communication by educational research in general (Cazden and Beck, 2003) and by science educational research in particular (Lemke, 1990; Roth and Lawless, 2002). Educational objectives require students to understand science concepts but also to develop an ability to express their understanding of science concepts in spoken format (Carlsen, 2010). This is further complicated when the language of instruction is different from students' mother tongue. Addressing how learning science can be promoted in CLIL classrooms is paramount to this study. This objective was primarily accomplished by examining how discourse practices facilitate opportunities for learning science when a CLIL approach is adopted at upper secondary level. Secondarily, it was accomplished by investigating the perspectives of teachers and students about the phenomenon of learning science through a CLIL approach.

7.3 Overview of Study Design

This study intended to deviate from the mainstream research about CLIL and to position itself in the niche of science education research focused on language (Carlsen, 2010; Espinet, Izquierdo, Bonil and De Robles, 2012; Sutton, 1998) when a communicative approach to learning is adopted (Sfard, 2008). It conceptualizes science learning as a social and situated practice (Greeno, 1998; Rogoff, 1998) and considers language as a resource for learners and teachers (Ruíz, 1984). In order to investigate how science learning is built through classroom discourse within a sociocultural perspective of learning, three case studies (Stake, 1995) were investigated using mixed methods (Tashakkori and Teddlie, 2003) within a pragmatist epistemology (Johnson and Onwuegbuzie, 2004). In particular, three upper secondary groups of CLIL biology classrooms from three schools, two in Germany and one in Italy, were selected as the sample. Learning environments were investigated in terms of classroom discourse, teachers' beliefs and students' perceptions. To collect evidence of these three perspectives, classroom discourse was systemically observed and audio-recorded, teachers were interviewed and questions were put to students through a questionnaire. The analysis was conducted on a corpus of approximately 120,000 words of transcribed interactions, 34 hours of observational data, three interview transcripts and 160 completed questionnaires. Classroom discourse was analysed both in terms of interactions productive for science learning (discourse analysis on classroom interactions) and in terms of teaching practices (thematic analysis). Teacher interviews were analysed through thematic analysis and a descriptive statistical analysis of frequencies was conducted on questionnaire responses. Findings from different sources of data were integrated in the interpretative final phase.

7.4 Overview of Findings

The overall purpose of this study was to investigate how opportunities for learning science are promoted in biology classrooms at upper secondary level when a CLIL approach is implemented. The focus of the investigation was on examining classroom discourse practices, teachers' beliefs and students' perceptions in relation to the research problem. The following research questions framed the overall purpose:

1. What interactional discourse practices promote opportunities for learning science when a CLIL approach is implemented at upper secondary level? (RQ1)
2. What teaching discourse practices promote opportunities for learning science when a CLIL approach is adopted at upper secondary level? (RQ2)
3. What are teachers' goals and epistemological beliefs about teaching science through a CLIL approach and how do they affect classroom practice? (RQ3)
4. What are upper secondary level students' perceptions of learning science through a CLIL approach? (RQ4)

Accordingly, findings were interpreted in order to obtain understanding of opportunities for learning science in CLIL settings at upper secondary level in relation to (1) interactional discourse practices, (2) teaching discourse practices, (3) teachers' goals and beliefs, and (4) students' perceptions.

In the next sections, key findings are outlined in relations to each research question.

7.4.1 What interactional discourse practices promote opportunities for learning science when a CLIL approach is implemented at upper secondary level?

First, it was found that teachers' questioning—embedded in extended forms of triadic dialogue (i.e. IRFRFRF sequences)—dominates the classroom dialogue, which confirms the results of other studies conducted in L1 science classrooms (Dillon, 1988) and L2 cross-disciplinary classrooms at primary level (Boyd and Rubin, 2002). More importantly, it was demonstrated that a teacher's questioning promotes conceptual understanding in the CLIL science classroom, which confirms what was found in L1 science classrooms (e.g. by Chin, 2007; Smart and Marshall, 2013; Yip, 2004) but never before in bilingual classrooms. In particular, it was found that higher order thinking (HOT) questions promote both cognitive engagement (schematic and strategic knowledge) and science language development. However, high cognitive engagement only takes place when students verbally communicate by using an appropriate language, as the two aspects—cognitive engagement and language use— were inseparable. This result confirms Vygotsky's theory of thought and language (Vygotsky, 1986). Summing up, *opportunities for learning science in the CLIL upper secondary classroom are promoted by HOT questioning. HOT questioning only works when students verbally communicate their thoughts beyond the one-word answer*.

Secondly, when HOT questions are strategically placed and contingent on students' answers (e.g. by probing students or asking to expand), it can also lead to sensemaking. Cognitive engagement and sensemaking are both cornerstones of science learning in general and of conceptual understanding in particular (Odden and Russ, 2019; Smart and Marshall, 2013). Therefore, their presence in upper secondary CLIL science classrooms is an indicator that opportunities for learning science are both provided and employed by the learners. In this data, sensemaking is dependent on a teacher's strategic/contingent questioning (see Alexander, 2001) and on students' language use, which always entails some form of verbal production by the students beyond the one-word utterances. However, language use in a CLIL classroom may mean many different things, in particular when an orientation of language-as-resource is adopted. In these data, sensemaking is supported both by translating science language into students' everyday language (Brown, 2006; Brown and Spang, 2008) or into the students' mother tongue (cf. Warren *et al.*, 2001). In this way, science language makes sense and science content becomes meaningful to students. To sum up, *opportunities for learning science in the CLIL upper secondary classroom are promoted by strategic and contingent questioning that builds on students' utterances (e.g. probing and extending) and that eventually leads to sensemaking. The process is facilitated by translanguaging practices*.

Thirdly, CLIL students often do not have the linguistic resources to effectively participate and interact in productive and cognitively engaging classroom discourse. This issue may result in limiting students' opportunities for learning science, which would confirm Cummins' threshold hypothesis (Cummins, 1976). However, the adoption of a language-as-resource orientation by both teachers and students supports verbal communication in CLIL upper secondary science classrooms. This means that, when translanguaging practices become normalized, they facilitate access to the science dialogue. Translanguaging practices have been observed to create a discursive space where students can verbally elaborate their thoughts and overcome conceptual gaps. In this space, more students manage to participate in classroom discourse, to have their answers checked and to dialogically build meanings. In addition, translanguaging practices were observed to promote the development of L1 academic language. Overall, *opportunities for learning science in the CLIL upper secondary classroom are facilitated by translanguaging practices, as these promote participation in classroom dialogue, conceptual understanding of science content and development of L1 specific language.*

Fourthly, teachers were observed to also ask language-related questions. These questions promoted both conceptual understanding (by checking students' linguistic comprehension) and science language development (by prompting its use). Language-related questions can lessen the linguistic barriers that limit content access in the CLIL classrooms (see Kääntä and Kasper, 2018) and help students develop the language of the discipline (see also Ernst-Slavit and Pratt, 2017). In addition, they promote science sensemaking when they request students to provide the explanation of a technical term by using their own language (cf. Odden and Russ, 2019). Therefore, this study provided evidence that *opportunities for learning science in the CLIL upper secondary classroom are promoted by language-related questions, which promote both conceptual understanding and science language development.*

Fifthly, in this study, students' questions were not particularly frequent and they were not evenly distributed across the three case studies. In addition, students' questions tended to be content-related, instead of language-related, which is contrary to what Dalton-Puffer (2007) found in her study on CLIL classroom discourse (but not specifically science classroom discourse). Being at the heart of scientific inquiry, students' questions play an important role in contributing to science learning (Chin and Brown, 2002). In particular, in this study, it was demonstrated that students' conceptual clarifying questions contributed to promoting both academic language development and students' cognitive engagement. This happens for the very nature of the cognitive questioning process, meaning that, for asking questions, students need to pin down their conceptual gap and verbalize it (Koole, 2012). In addition, when the teacher answers a student's question, the student gets a specific answer to his or her puzzlements. Translanguaging practices were observed to facilitate students asking questions. Overall, the study provides evidence that *opportunities for learning science in the CLIL upper secondary classroom are promoted by students' questioning.* What aspects of the classroom environment or of the teaching approach facilitated students' questions is not clear. However, it was noted that students asked more questions when they perceived it as an easy task. The directionality of this relationship between perception of task demand and behaviour is not clear (i.e. is the perception of it being an easy task leading to a higher rate of questions or vice versa).

Lastly, the following interactional strategies were also observed to promote or facilitate conceptual understanding and/or science language development (Table 7.1).

Table 7.1 Interactional strategies that promote opportunities for learning science in the CLIL upper secondary classroom.

Interactional strategies	Conceptual understanding	Science language development
- Giving time to discuss problems first with peers	✓	✓
- Rephrasing questions to make them clearer	✓	
- Rephrasing questions to expose students to the lexical repertoire they need for answering them		✓
- Increasing wait time for answers	✓	✓
- Giving clues to nudge thinking in the right direction	✓	
- Using strategic placement of questions (e.g. by probing, challenging, asking for extending)	✓	
- Using contingent questioning: long answers are split in chunks		✓
- Inviting to use any language for answering	✓	✓

7.4.2 *What teaching discourse practices promote opportunities for learning science when a CLIL approach is implemented at upper secondary level?*

The analysis of classroom discourse revealed that a teachers' discourses were focused on science content, science nature and science language in all three case studies. The focus on science content was dominant and explicit. However, embedded in the discourse texture, elements that relate to the Nature of Science and to science language development were also present. As evidenced by the literature reviewed at the start of this research study, there is a growing consensus that teaching how science works is at least as important as teaching the content of science knowledge (Lederman, 2007). In addition, it was also highlighted how science language constitutes a "hidden curriculum" (Cazden, 1993, p. 12) that is "symbiotic" to science content (Richardson Bruna *et al.*, 2007, p. 50). The presence of these elements in the classroom discourse influences the opportunities students have to learn science (as understood by Stevens, 1993).

Several teaching strategies were observed to promote the building of science content (and conceptual understanding in particular), of NOS understanding and of science language. First, **translanguaging practices** were, in this study, not only identified as an interactional strategy—as described above—but also as a teaching strategy, meaning that the teachers in this study were observed deliberately switching between linguistic codes for teaching purposes. Like in Lin and Lo (2017), also in this study, the meaning of translanguaging is extended to comprise the dichotomy of everyday/academic language. Both everyday language and the students' first language were considered important linguistic resources for building meaningful knowledge. In particular, all three teachers were observed switching between academic and everyday language through the rhetoric device of direct quoting for supporting conceptual understanding. This finding resonates with what Brown and Spang (2008, p. 731) found in multilingual science classrooms about the potential for teachers' "hybrid discourse" (i.e. the mixing of casual forms of language with formal ones) to give students a vision of science as connected to their personal and collective experiences and not as opposed to them. In addition, two of the teachers were also observed switching to L1 for promoting conceptual understanding, participation in classroom discourse (e.g. by inviting to use any language) and the contextual development of the L1 academic language (e.g. when asking for translations). In other studies, it was found that teacher's translanguaging also influences students' linguistic identities (cf. Brown and Spang, 2008) and promotes ideologies of linguistic inclusion (cf. Lemmi *et al.*, 2019). To sum up, *opportunities for learning science in the CLIL upper secondary classroom are promoted by teachers' translanguaging practices between L2 and L1 and between academic language and everyday language.*

Secondly, **metadiscourse** was identified as a versatile and powerful tool in the hands of a science teacher in CLIL upper secondary classrooms. In particular, organizational metadiscourse makes connections more explicit and helps students to better orient themselves throughout the lessons and throughout the development of the curriculum. Attitude markers signal importance or difficulty and interpretive markers help students to grasp the appropriate interpretations and meanings of science content. Epistemology markers and attitude markers have been observed to support the transmission of science values and epistemologies and therefore to promote the building of the Nature of Science understanding. In a CLIL classroom, metadiscourse also allows teachers to be responsive to students' language needs and guides students to grasp the correct meaning of words (especially academic terms). Overall, *opportunities for learning science in the CLIL upper secondary classroom are promoted by teachers' use of metadiscourse, which proved to be a useful and versatile tool for assisting conceptual understanding, NOS understanding and science language development.*

Thirdly, closely related to metadiscourse is the concept of **metalanguage**, i.e. a language for talking and reflecting on language (Hyland, 2017). In this study, metalanguage was mainly used for developing science language by explicitly embedding it into the disciplinary discourse. This finding stands in contrast with what both Vollmer (2008) and Nikula (2017b) found in CLIL classrooms, where academic language never explicitly surfaced. By contrast, in this study, science language development is actively supported by the teacher's use of metalanguage. In addition, academic language was often introduced by expressions such as "we say", "we call". These linguistic forms had the power to influence the building and shaping of what Lave and Wenger (1991) conceptualized as communities of practice. Overall, *opportunities for learning science in the CLIL upper secondary classroom are promoted by a teacher's use of metalanguage*.

Fourthly, **redundancy strategies** such as paraphrases, synonyms, rephrasing of questions and re-teaching promote both conceptual understanding and content memorization. In addition, these practices also support the development of academic language and of science literacy, in particular, of the micro-genre of definitions (Dalton-Puffer, 2007, p. 132). Therefore, *opportunities for learning science in the CLIL upper secondary classroom are promoted by a teacher's use of redundancy strategies.*

Lastly, in the CLIL science classrooms observed in this study, conceptual understanding is also promoted by the use of examples, analogies, anecdotes and direct quotes, which help both memorization and understanding processes. Each science teacher seems to possess a **personal style for explaining** scientific concepts that favour one strategy or another, and that resonates with her or his personality and that, for this reason, works well with her or him.

7.4.3 What are teachers' goals and epistemological beliefs about teaching science through a CLIL approach and how do they affect classroom practice?

All three teachers of this study see themselves predominantly as science teachers and all basically share similar science teaching goals and a typical science teaching culture. Despite having taught for years through a CLIL approach, they have not modified their professional identity. This finding confirms the results of a Dutch study on CLIL teachers (van Kampen *et al.*, 2017). In the present study teachers unanimously consider the CLIL approach to science learning as an opportunity for their students to acquire and improve a skill for life, which is not the acquisition of a foreign language *per se*, but rather the ability to learn through a foreign language or to communicate in multilingual contexts. The adoption of a CLIL approach is also perceived as a challenge by all three teachers. The specific reasons are different but they are all language-related. For instance, all three teachers considered both active participation in classroom discourse and conceptual development to be at some risk in a CLIL teaching and learning context.

In terms of language beliefs, these teachers positioned themselves in different ways. In relation to students' language use, the two following orientations were observed:

A. A student's language is an instrument for understanding what is being explained. It is important for students to "think and to understand" rather than to verbally produce as science learning "doesn't require a lot of language" (quotes from James' interview).

B. Language has a value for its own sake. Accordingly, science students need "to develop the language of science". The line between understanding and speaking about science can be rather blurred and when students are not able to *speak* about science their *understanding* of science is questioned. Participation in classroom discussions is important for knowledge building (quotes from Emma's interview).

When these two opposing beliefs about language were crossed with findings about questioning practices, they appear to be related (see Table 7.2).

Table 7.2 Relationship between teachers' language beliefs and classroom questioning.

Teacher's language belief	Teacher's questioning	Students' answers
A - Language is a tool for understanding someone else's production; students' verbal engagement is unnecessary	Dominance of LOT questions (GWTT questions in particular)	Dominance of short, one-word answers (display of declarative knowledge)
B - Language is an integral part of science and science speaking is part of science learning	High frequency of HOT questions	Dominance of long answers (display of declarative + schematic knowledge)

Despite the value of these findings, I cannot claim a causal relationship between a teacher's language belief and specific classroom questioning practices. The findings of this study are limited in their ability to make such assertion due to the research design and an analysis that involved a small sample. Despite this limitation, the evidence collected calls for greater attention to be given to the impact of language beliefs in the CLIL science classroom. To conclude*, teachers' epistemological beliefs about language effect opportunities for learning science in the CLIL upper secondary classroom.* In particular teachers' epistemological beliefs about language appear to effect students' verbal engagement, students' participation in classroom discourse, and, indirectly, also cognitive engagement.

The teachers in this study demonstrated different language beliefs also in relation to translanguaging practices. Whereas both Alexandra and Emma—the two non-native English-speaking teachers—valued the bilingual dimension of language as a resource, James, the native English-speaking teacher, seemed unable to acknowledge the resource of bilingualism, which confirms what García-Nevarez *et al.* (2005) observed in bilingual programmes in the US. The effects of this epistemological belief about translanguaging transpire in student questionnaire responses, where most of James' students consider translanguaging practices as uncommon or non-existent. By contrast, Alexandra and Emma acknowledge bilingualism and, in their classrooms, students perceive and use translanguaging practices as resources to access science and as a means to participate in classroom discourse. It can be concluded that Alexandra and Emma have a language-as-resource orientation when it comes to translanguaging, meaning that they share an inclusive ideology about language. In contrast, James favours a monolingual approach to language use. However, all three teachers appear to share a language-as-resource orientation when it comes to alternating the use of academic and everyday language in the classroom.

7.4.4 What are upper secondary level students' perceptions of learning science through a CLIL approach?

Overall, questionnaire responses across case studies have revealed that most of the students in all three case studies perceive themselves as actively involved in the process of science learning. Science explanations are usually perceived as accessible and in general the CLIL setting does not appear to be a source of concern. For these upper secondary CLIL students, neither the lexically dense biology language (Halliday, 2002, p. 176) nor the comprehension of biology concepts are problematic.

Most of the scales show results that are relatively consistent across case studies, with the notable exception of the items referring to the use of L1. Most of James' students perceive that only rarely are words translated to L1, that the teacher almost never uses L1 for facilitating conceptual understanding and only a minority of James' students think they can use L1 when they need to. These results are corroborated by both observational data and teacher interviews and may be explained by the fact that James is a native English speaker (see García-Nevarez *et al.*, 2005). However, these data also suggest that in James' classrooms some real opportunities to access science and therefore to learn science are lost because the students' first language is not exploited as a learning resource.

7.5 Conclusions and Contributions

In this section, specific findings and conclusions from this study are outlined in terms of their contribution to international science education research concerned with bilingualism and/or to European CLIL education research.

- As evidenced by the literature review, only a few studies have so far specifically addressed science learning in CLIL settings. In addition, most of these studies have not been published in English (e.g. Bonnet, 2004; Kircher, 2004). This research study contributes to deepening our understanding of science learning in a CLIL context. In relation to CLIL research, it offers an alternative perspective with which one can look at learning processes in CLIL settings to understand the intricate relationship between science learning and language.
- The adoption of a language-as-resource orientation by CLIL teachers at upper secondary level supports opportunities for learning by promoting participation in classroom discourse, students' cognitive engagement and conceptual understanding. Adopting a language-as-resource perspective means embracing an ideology of inclusion towards language that leads to using the multilingual resources available in the classroom. This perspective is opposed to language-as-problem perspectives that advocate strict adherence to the target language as a prerequisite for language learning. The language-as-resource perspective challenges the typical conceptualisation of language as educational goal in CLIL research (see, for instance, Dalton-Puffer, 2007). If we look at CLIL from the perspective of content learning and through a lens of language-as-resource, language is something more profound and transversal than a standardized instructional goal. To date, virtually no research has been conducted on CLIL science teachers' orientations to language and how these influence science teaching (cf. Skinnari and Bovellan, 2016). So far, this is one of very few studies in science education that explicitly refer to language-as-resource and the first one in science education that is concerned with classroom practices (the other one is by Lemmi *et al.*, 2019, on US teachers' language ideologies). The adoption of such an orientation is reflected in the normalization of translanguaging practices in the classroom.
- This study contributes to the CLIL discussion about translanguaging practices as pedagogical practices (Garcia and Wei, 2013; Moore and Nikula, 2016). When translanguaging between L2 and L1 and between academic language and everyday language becomes normalized in the upper secondary

science classroom, it facilitates access to science dialogue. Through utilising translanguaging more students manage to participate in classroom discourse. Furthermore, when employed by the teachers, translanguaging practices promote conceptual and linguistic understanding and the development of L1 academic language. Translanguaging is one aspect of European CLIL research that has received relatively little research attention (Nikula, 2017a). This study is among the first to investigate translanguaging for supporting science learning in CLIL classrooms (see Moore and Dooly, 2010; Moore *et al.*, 2016) and builds on findings from research in other approaches to bilingual education (e.g. Esquinca *et al.*, 2014; Ünsal, Jakobson, Molander and Wickman, 2018).

- Teachers' questioning promotes conceptual understanding in the CLIL science classroom, which confirms what was found in L1 science classrooms (e.g. by Chin, 2007; Smart and Marshall, 2013; Yip, 2004). This study is one of the first research studies in science education to closely look at a teacher's questioning as a tool for promoting science understanding in bilingual settings. In this regard, the study builds on and expands what Ernst-Slavit and Pratt (2017) demonstrated in linguistically diverse US science classrooms at primary level. In particular, this study demonstrated that higher order thinking (HOT) questions promote both cognitive engagement (schematic and strategic knowledge) and science language development. In this study, high cognitive engagement was observed when students orally communicated their thoughts beyond the one-word answer, as the two aspects—cognitive engagement and language use—were connected. This result confirms Vygotsky's theory of thought and language (Vygotsky, 1986).
- Science sensemaking in upper secondary CLIL classrooms is promoted when teachers' questions are strategically placed and contingent on students' answers. This process is facilitated by translanguaging practices, meaning that science content becomes meaningful to students when it builds upon students' everyday language (e.g. when students explain science by "using their own words") and students' mother tongue. Up to now, there has been little research on sensemaking in bilingual science classrooms (see Brown *et al.*, 2005; Esquinca *et al.*, 2014; Warren *et al.*, 2001). This is the first study focused on sensemaking for building science content in CLIL classrooms.
- In the upper secondary CLIL science classroom, teachers' language-related questions promote both conceptual understanding (by checking students' linguistic comprehension) and science language development (by prompting

its use). This finding builds on and expands what Ernst-Slavit and Pratt (2017) found in linguistically diverse primary US classrooms.

- How an upper secondary CLIL teacher interrogates students about science content in terms of language demand and cognitive engagement appears related to a teacher's beliefs about language. Language can be either conceptualized as a tool for understanding or as in integral part of science learning. In this study, these two contrasting beliefs resulted in different learning environments. In particular, when language was conceptualized as a tool, questioning practices that requested low cognitive engagement and limited verbal communication dominated. By contrast, when language was conceptualized as part of the science curriculum, students were observed to engage in a more evolved verbal communication at a higher level of cognitive engagement. Even though further research is necessary to investigate the possible relationship of causality between language beliefs and learning environments, this finding indicates that an attention to how teachers interpret language for learning in CLIL settings is needed. This is the first study that addresses teachers' language beliefs for their potential to effect classroom practices in a research field different from foreign and second language teaching (e.g. Borg, 2003; Farrell and Kun, 2007). In CLIL research, Hüttner *et al.* (2013) examined teachers' language beliefs for their potential to effect language teaching, but their study does not provide any insights into how language beliefs influence the teaching of disciplinary content.

- Content-related student questions are present in the science CLIL upper secondary classroom. This finding contradicts what Dalton-Puffer (2007) found in her study on CLIL classroom discourse (but not specifically science classroom discourse), where students' questions tended to be language-related. These findings contribute to depicting a new image of the CLIL classroom, closer to the traditional science classroom where students' questions are at the heart of scientific inquiry and play an important role in contributing to science learning (Chin and Brown, 2002). Furthermore, in this study, students' conceptual clarifying questions contribute to promoting both academic language development and students' cognitive engagement. However, what aspects of the classroom environment or of the teaching approach facilitate students' questions is not clear. This finding is particularly significant for European CLIL research. However, it also extends its contribution to international science education research by demonstrating how a particular category of students' questions impact on science learning in bilingual settings.

- A teacher's use of metadiscourse in an upper secondary CLIL classroom mediates conceptual understanding and science language development. In a CLIL classroom, metadiscourse also allows teachers to be responsive to students' language needs and guide students to grasp the correct meaning of terms and scientific content. These findings build on and expand what Msimanga and Erduran (2018) found about argumentation-based teaching in multilingual South African science classrooms where English is the main language of instruction. The present study is the first to address metadiscourse in bilingual science classrooms with the purpose of investigating science understanding beyond classroom argumentation.
- Teachers' use of metadiscourse in the upper secondary CLIL classroom also supports the development of science epistemologies and science values (Nature of Science). In particular, epistemology and attitude markers mediate the teaching of NOS in the CLIL classroom discourse and shape students' idea of science. This is the first study to address the teaching of the Nature of Science in bilingual classrooms discourse beyond the concept of *cultural congruence*, meaning the compatibility of instructional/scientific practices with students' language and culture (see Lee and Fradd, 1996a). These findings build on and expand what Ryder and Leach (2008) found in L1 classrooms about how teachers transform their personal understanding of science epistemologies into classroom discourse. These findings are particularly significant for international science education research concerned with bilingual environments.
- Teachers' use of metalanguage, i.e. the talking about language, supports the development of science language by making it visible in the classroom discourse. This finding contrasts with what Vollmer (2008) and Nikula (2017b) separately found in CLIL classrooms, where academic language never explicitly surfaced. Furthermore, in this study, academic language was often introduced by expressions such as "we say", "we call", which contributed to building and shaping communities of practice (Lave and Wenger, 1991).
- Teachers' intense use of redundancy strategies (e.g. paraphrases, synonyms, rephrasing of questions and re-teaching) in the upper secondary CLIL classroom promotes conceptual understanding, content memorization and science language development. In particular, repetitions and paraphrases enhance communication through stronger messages, help avoid misunderstandings and guide the focus to meaningful elements. In addition, students are exposed to alternative ways to express the same concept, which promotes the building of meaningful scientific content (Lemke, 1990). By

restating students' answers, teachers mark the importance of each student's contribution in the generation of a shared common knowledge (Edwards and Mercer, 1987). Reformulations of students' utterances promote science literacy development through practicing the micro-genre of definitions (cf. Dalton-Puffer, 2007, p. 132). These findings provide support for and extend to bilingual education what Duff (2000) and Skehan (1998) found in studies in second language acquisition.

To sum up, in the international field of science education, this research makes a significant contribution to our understanding of how science learning is interactionally and situationally constituted and made visible in bilingual classrooms. As outlined above, many aspects that this study investigated about science classroom discourse had not been investigated previously in bilingual/CLIL settings (e.g. the use of questioning and metadiscourse for promoting conceptual understanding, the use of translanguaging practices, the teaching of the nature of science). In addition, this study makes a significant contribution to the European debate on CLIL.

It is worth noticing that the self-selected sample and the relatively small sample size limits the generalizability of the findings and the causality relationships between variables. Overall, the limitations of this study were discussed in detail in sections 1.8 and 4.22.

7.6 Recommendations

This study has generated some significant insights into the dimension of science learning when a CLIL approach is implemented. This section will outline some recommendations for teaching practices and for teacher education based on the key findings from this research.

7.6.1 Recommendations for Teachers' Practice

The focus of this investigation has been on discourse practices in CLIL classrooms for supporting and promoting science learning at upper secondary level. Among other things, the research demonstrates how teachers matters in generating opportunities for learning science, both in terms of actions and in terms of personal beliefs. The following are a number of specific suggestions for teachers that could be considered when designing and implementing a CLIL approach in science education.

- It is important for teachers not to over-simplify the linguistic demand of students' tasks (such as answering to questions). Over-simplifying the oral communication that students are expected to produce—by limiting the requests to one-word answers—leads to an over-simplification of disciplinary content in terms of cognitive engagement as language and thought development are tightly connected (Vygotsky, 1986). This approach deprives students of important opportunities for learning science and makes science content less appealing to upper secondary learners. Instead, this study identified some practical strategies to scaffold, both cognitively and linguistically, productive questioning in science CLIL classrooms (e.g. probing, translanguaging) that worked for the investigated classrooms (upper secondary level) and that could also work outside the context of this research.

- The examples from this study offer suggestions that may be used by CLIL teachers embed more successfully the teaching of science language in the classroom discourse. For instance, it was observed that the CLIL science teachers who participated in this study often interrogated their students about the meaning of academic words. They also prompted students to use science language by asking dedicated questions. In addition, teachers can use metalanguage to explicitly "speak" about the language of science. Science teachers may not feel comfortable enough to explicitly teach language (Airey, 2012). The findings of this study may have the potential to dispel the notion that language teaching is neither a science teachers' responsibility nor a significant aspect of science teaching and learning, CLIL or non-CLIL. Overall, when considering the results of this study in conjunction with other research about language and science learning, probably the most important implication for teaching that emerges is that language plays an important role in how science knowledge, science values and science identities are shaped:

> Many science teachers simply fail to pay attention to how complicated their language is when they teach science. The potential role language may play in intimidating students is particularly important [...] as the genres of academic language are inherently markers of culture and identity.
>
> (Brown *et al.*, 2019, p. 16)

  In this sense, the examples provided by this study may also provide interesting food for thought for also non-CLIL science teacher.

- The findings of this study offer examples of translanguaging practices employed in CLIL science classrooms. Such practices engage students' language repertoires holistically using languages as resources for building science. By including students' first language and everyday language in the classroom dialogue, students are offered better opportunities for understanding and learning science and for developing science language also in their mother tongue. Furthermore, this study provides evidence that when it is the teacher who implements these practices, students tend to appropriate the teacher's language practices and mirror them. Ultimately, teachers have the power to shape learning environments that promote science learning by designing students' discursive behaviours. These considerations have important implications for the development of teaching practices and may help CLIL teachers to reflect on their use and conceptualization of language.

- Students' questions were observed to be important for promoting conceptual understanding, oral communication about science, and for boosting students' confidence. Based on this evidence, a classroom culture that stimulates and encourages students' questions is desirable for promoting opportunities for learning science.
- Finally, findings from this study suggest that each science teacher possesses a personal style for explaining scientific concepts that may favour one or more teaching strategies (for instance, the use of anecdotes, funny stories, direct quotes). These strategies resonate with a particular teacher's personality and, for this reason, work well with that particular teacher. Ideally, teachers should not abdicate their most natural way of explaining science. However, CLIL teachers may be constrained by linguistic barriers possibly resulting in restricted repertoires of teaching pedagogies. This study offers examples of how CLIL teachers may scaffold their teaching with other teaching strategies (e.g. metadiscourse, linguistic redundancies, translanguaging).

7.6.2 Recommendations for Teachers' Education Programmes

Secondary schools throughout Europe are faced with an increasing demand for providing science in English using CLIL as an approach (Zydatiß, 2017). As a result, increasing numbers of pre-service and in-service science teachers are engaging in training courses and workshops to get ready to implement CLIL in their classrooms (Pérez Cañado, 2016a). Findings from this study can contribute to informing CLIL teacher education programmes, especially those related to science teaching. While an analysis of CLIL science teachers' needs is beyond the scope of this study, the following insights can inform teacher education programmes and research:

- Science teachers need to reflect on how they conceptualize language for schooling. Even though this study did not establish a cause-and-effect relationship between teachers' language beliefs and the learning environments they create, the findings seem to suggest that there is a relationship between how teachers conceive language and how students verbally communicate and are cognitively engaged. Furthermore, language beliefs also appear to be reflected in language practices such as translanguaging. However, these beliefs are unconscious (Borg, 2003), and their rationalisation may be better prompted with the help of professionals who help teachers to reflect on their work. For this reason, this aspect of CLIL teaching would be better tackled in CLIL teacher education programmes, where personal pre-existing beliefs about language can be explored. Subsequently, extracts and findings from this study could be used to exemplify these aspects of science teaching in CLIL settings
- This study offers exemplars of how different teachers, with different professional backgrounds and different epistemological beliefs, effectively incorporated linguistic aspects into their teaching without compromising the rigor of science content and processes. These exemplars may be used in teacher education programmes to raise awareness of the role of spoken language in science classroom discourse for building conceptual understanding.
- This study provides evidence that science learning in CLIL classrooms benefits from the implementation of contingent questioning strategies, meaning that teachers' questions build on students' previous contributions. This dialogue practice promotes conceptual understanding, students' oral communication in science and sensemaking. In particular, the splitting of the thinking process into cognitively more manageable steps prompted by a teacher's questions is mirrored by the splitting of the students' verbal production into more manageable chunks of speech, which lessens the linguistic demand for CLIL students. As effective questioning is something that can be learnt through both experience and observation of other experienced teachers (Bandura, 1986), CLIL science teachers may greatly benefit from observing other teachers using questions to effectively build science knowledge in CLIL settings (cf. Smart and Marshall, 2013). Also, the examples collected in this study may provide a useful basis for discussion.

- According to the findings from this study, linguistic redundancy is a desirable practice for scaffolding teaching in CLIL settings. Therefore, CLIL teacher education could benefit from this finding and plan to include an effective use of linguistic redundancies into interventions aimed to prepare teachers for effective science teaching while adopting a CLIL approach.

7.6.3 Recommendations for Policy

In light of how European societies are changing as a result of an "unprecedented global mobility" of people (IOM - International Organization for Migration, 2017, p. 305), a growing linguistic heterogeneity in mainstream classrooms is expected. CLIL education and CLIL teachers may represent a key asset for tackling the changing student population that is attending schools all over Europe. CLIL science teachers tend to be more sensitive to the role that language plays in the science classroom and more responsive to students' linguistic needs. Furthermore, an orientation of language-as-resource may offer better educational opportunities for multilingual science students (Planas and Civil, 2013). Academic achievements of many multilingual students may improve by changing how schools and societies regard languages and what teachers consider appropriate for the classroom (Flores and Rosa, 2015).

7.7 Future Research Directions

Empirical CLIL research into content aspects is still too scarce and inconclusive to inform policy. In addition, more subject-based research into CLIL from specific disciplinary perspectives is needed to explicitly support and guide practitioners to fully capitalize on the benefits of bilingual education. I wish to make a number of suggestions for future research based on the findings from my study and specific to science education.

- As findings from this study on discourse practices are not generalizable because of methodological limitations, further research is needed to confirm the present findings with larger samples and in different locations.
- Research is also needed to establish issues of causality that this study was not able to solve. For instance, linking specific language beliefs to teachers' discourse practices (e.g. questioning) would have a great instructional impact. In particular, it would be advisable to investigate on a larger scale how teachers' conceptualization of language for learning influences learning environments in CLIL science classrooms in terms of students' conceptual understanding, cognitive engagement and science language use. In this study,

two orientations towards language were identified specific to science teachers in CLIL settings (Table 7.2), but it is likely that a wider range of different language belief systems influence teachers' classroom practice. More research is necessary on how science teachers think about language for learning and how these epistemological beliefs affect and effect their instructional practices.

- In this study, translanguaging practices were both recurring and useful for promoting conceptual understanding and science sensemaking. Further research would be particularly helpful to better examine the potential of translanguaging practices in the CLIL science classroom. In particular, further research with larger samples, in other locations, and with learners from different age-groups and with different L2 competences is needed to understand how these practices are connected to teachers' language ideologies.
- This study was focused on whole-class discourse practices. Further research is necessary to examine other pedagogical approaches, such as peer discourse or science writing, employed in science CLIL classrooms. In addition, a longitudinal approach to research design could monitor the development of students' language, learning skills and confidence.

7.8 Final Comment

The idea of this doctoral study originated in my own experience of teaching science at upper secondary level using a CLIL approach. I wanted to highlight and explore some of the difficulties I was experiencing as well as questions arising from my practice. Also, I hoped that a thorough investigation of CLIL science classroom discourse and science learning could inform and support other teachers experiencing difficulties and uncertainties in similar situations. What this investigation has demonstrated is that there are many challenges that CLIL instruction has to cope with when confronted with building science content (e.g. conceptual understanding promoting, science language development, science values and science nature teaching, collaboratively and interactionally discussing and building content). But what this investigation has also highlighted are the benefits that derive from approaching science learning by using a language that is not the first language of the learners, such as a greater language awareness and larger linguistic resources. The task lies in harnessing language resources and implementing teaching support measures and discourse practices that will enhance science learning.

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APPENDICES

Appendix A - Teacher Interview Schedule

Semi-Structured Interview Schedule

PART 1 <*factual information*>

Probe: Background of the teacher and the students (in general) in relation to science and CLIL teaching.

1. How long have you been teaching Science through English?
2. What age of students do you teach? How many lessons do students have per week?
3. Could you describe your classes in terms of students' attitude to learning in general, learning science, learning through English? *(very briefly)*

Probe: What are the teacher's teaching goals, strategic and pedagogical choices, design and conduct of lessons?

4. Could you tell me what does your teaching practice look like?
5. What is your general goal in teaching Science using a second language for the students?
6. How planning for instruction is affected by consideration of students' limited proficiency in the language of instruction.
7. Could you tell me what you do when the demands of curriculum exceed the linguistic skills of your student?
8. What kind of activities do you use more often / find more effective?

PART 2 <*effects/perceptions of CLIL on teacher's professional activity* >

P*robe: effects of CLIL on teacher's professional activity*

1. Based on your observations, how does the adoption of CLIL impact on the learning of science?
2. How has the adoption of CLIL shaped the way you communicate with students?
3. How has the adoption of CLIL shaped your "teaching style"?
4. How has the adoption of CLIL shaped the way you manage your classrooms and discipline your students?
5. How do you think the CLIL approach can facilitate or constrain the students' engagement?
6. What did you find is most troublesome in your lesson? What makes that happen? And how do you alleviate the problem? Is that effective?
7. Can you tell me a couple of things you would do differently if you were teaching to English native speakers?
8. Overall, does the adoption of CLIL make it easier or harder for you to carry out your professional roles and responsibilities?
9. What aspects of learning science in English do you think are more challenging

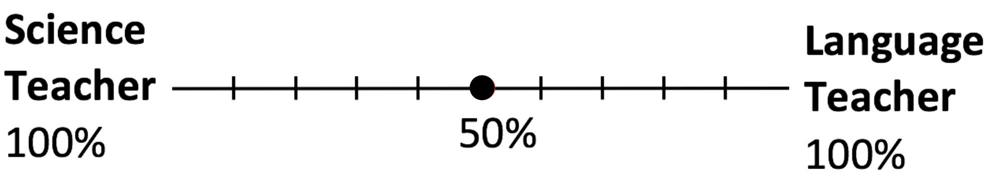
to students? How do you alleviate the issue?

10. What have been the biggest challenges or obstacles you have faced in adopting CLIL into your classroom pedagogy? (*Prompts: General resistance by colleagues and administrators / Time constraints / Pressure to teach to assessments / Lack of resources / Your own lack of comfort, knowledge or training with the second language or the methodology /Lack of external support)*

Probe: ambiguity of roles

11. On this scale, between this two extremes, what do you feel: a science teacher, a language teacher, both? Since when?

    The teacher is presented with the following Figure:



PART 3 < *ending questions*>

1. Could you tell me about how your beliefs about this practice may have changed since you have started teaching science using a CLIL approach?
2. Tell me about the strengths that you discovered/developed through teaching science using a CLIL approach? What advice would you give to a novice, a new teacher who is just starting to teach science using a CLIL approach?
3. Is there something that you might not have thought about before that occurred to you during this interview?
4. Is there something else you think I should know to better understand your point of view about teaching science with a CLIL approach?
5. Is there anything you would like to ask/add?

Appendix B – Students' Questionnaire

The "SCIENCE in ENGLISH CLASSROOM" STUDENTS PERCEPTIONS

NUI Galway
OÉ Gaillimh

DIRECTIONS FOR STUDENTS

1. This questionnaire asks you to describe your science classroom. There are no right or wrong answers. This is not a test. Your opinion is what is wanted.

2. Do not write your name, just your school and class. Your answers are confidential and anonymous.

3. On the next few pages you will find 50 sentences. For each sentence, circle one number corresponding to your answer.

For example (1):

	Almost Always	Often	Some-times	Seldom	Almost Never
In this class . . .					
the teacher asks me questions.	5	4	3	2	1

✓ If you think the teacher almost always asks you questions, circle the 5.
✓ If you think the teacher almost never asks you questions, circle the 1.
✓ Or you can choose the number 2, 3 or 4 if this seems like a more accurate answer.

For example (2):

	Very Difficult	Difficult	Neutral	Easy	Very Easy
In this class, how difficult is it for you to . . .					
pay attention	5	4	3	2	1

✓ If you think that paying attention is very difficult for you, circle the 5.
✓ If you think that paying attention is very easy for you circle the 1.
✓ Or you can choose the number 2, 3 or 4 if this seems like a more accurate answer.

4. If you want to change your answer, cross it out and circle a new number.

5. Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

6. Please give an answer for every question.

1

Please provide details in the box below:

School: ______________________________ Class: ______________________________________

Part 1 - What happens in this class?

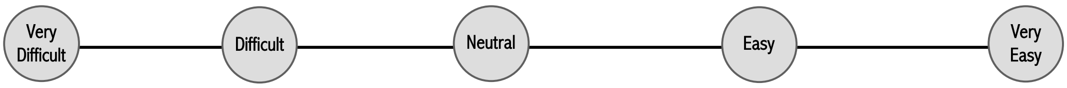
Almost always — Often — Some-times — Seldom — Almost never

		Almost Always	Often	Some-times	Seldom	Almost Never
In this class . . .						
1	I discuss ideas.	5	4	3	2	1
2	I perform experiments to test my ideas.	5	4	3	2	1
3	I learn about the world outside of school.	5	4	3	2	1
4	I learn that science cannot provide perfect answers to problems.	5	4	3	2	1
5	the teacher explains things in a way that is comprehensible to me.	5	4	3	2	1
6	I feel tense when I speak in English.	5	4	3	2	1
7	I give my opinions during class discussions.	5	4	3	2	1
8	I am asked to think about the evidence for statements.	5	4	3	2	1
9	my learning starts with problems about the world outside of school.	5	4	3	2	1
10	I learn that science has changed over time.	5	4	3	2	1
11	we translate English words into Italian.	5	4	3	2	1
12	I worry when I hear new or unfamiliar words.	5	4	3	2	1
13	the teacher asks questions to me.	5	4	3	2	1
14	I explain the meaning of statements, diagrams and graphs.	5	4	3	2	1
15	I learn how science can be part of my out-of-school life.	5	4	3	2	1
16	I learn that science is influenced by people's values and opinions.	5	4	3	2	1
17	the teacher uses more than one way of explaining a concept if the first explanation is not clear.	5	4	3	2	1
18	I worry about making mistakes.	5	4	3	2	1
19	my ideas and suggestions are used during classroom discussions.	5	4	3	2	1
20	I perform experiments to answer teacher's questions.	5	4	3	2	1
21	I get a better understanding of the world outside of school.	5	4	3	2	1
22	I learn that science is just one of many ways of understanding the world.	5	4	3	2	1
23	we use visual representations (e.g. maps, pictures, charts, models).	5	4	3	2	1
24	The class moves so quickly I worry about getting left behind.	5	4	3	2	1

2

		Almost Always	Often	Some-times	Seldom	Almost Never
In this class . . .						
25	I ask questions to the teacher.	5	4	3	2	1
26	I find out answers to questions by doing labs in class.	5	4	3	2	1
27	I learn interesting things about the world outside of school.	5	4	3	2	1
28	I learn that scientific knowledge is based on evidence.	5	4	3	2	1
29	the teacher uses Italian when we do not understand.	5	4	3	2	1
30	I would enjoy science more if lessons were in German.	5	4	3	2	1
31	I explain my ideas to other students.	5	4	3	2	1
32	I solve problems by using information obtained from experiments.	5	4	3	2	1
33	what I learn has nothing to do with my out-of-school life.	5	4	3	2	1
34	I learn that science is about inventing theories.	5	4	3	2	1
35	I can use Italian when I need to.	5	4	3	2	1
36	I would better understand science if lessons were in German.	5	4	3	2	1

Part 2 - How difficult are the following tasks for you?



		Very Difficult	Difficult	Neutral	Easy	Very Easy
In this class, how difficult is it for you to…						
37	learn new words	5	4	3	2	1
38	ask questions	5	4	3	2	1
39	answer questions	5	4	3	2	1
40	discuss	5	4	3	2	1
41	take notes	5	4	3	2	1
42	write about science	5	4	3	2	1
43	read textbooks in English	5	4	3	2	1
44	understand teacher's explanations	5	4	3	2	1
45	understand science concepts and ideas	5	4	3	2	1
46	work in small groups	5	4	3	2	1
47	do practical work (laboratories)	5	4	3	2	1
48	Cope with the pace of the lesson	5	4	3	2	1
49	stay focused	5	4	3	2	1
50	remember things	5	4	3	2	1

3

Appendix C – Questionnaire Scales

Scales and items of the *Learning Science in English* questionnaire and their literature sources.

SCALE /Source	***Items*** (*"In this class..."*)
Involvement /WIHIC	... I discuss ideas in class ... I give my opinions during class discussions ... the teacher asks me questions ... my ideas and suggestions are used during classroom discussions ... I ask the teacher questions. ... I explain my ideas to other students
Investigation /WIHIC	... I carry out labs in class to test my ideas. ... I am asked to think about the evidence for statements ... I explain the meaning of statements, diagrams and graphs ... I carry out labs in class to answer the teacher's questions. ... I find out answers to questions by doing labs in class. ... I solve problems by using information obtained from my own labs in class
Personal relevance /CLES	... I learn about the world outside of school. ... my learning starts with problems about the world outside of school. ... I learn how science can be part of my out-of-school life. ... I get a better understanding of the world outside of school. ... I learn interesting things about the world outside of school. ... what I learn has nothing to do with my out-of-school life.
Uncertainty of Science /CLES	... I learn that science cannot provide perfect answers to problems. ... I learn that science has changed over time. ... I learn that science is influenced by people's values and opinions. ... I learn about the different sciences used by people in other cultures. ... I learn that modern science is different from the science of long ago. ... I learn that science is about inventing theories.

Understanding and Communicating Science through a Second Language /new	… the teacher explains things in a way that is comprehensible to me … we translate English words into <German/Italian> … the teacher uses more than one way of explaining a concept if the first explanation is not clear … we use visual representations (e.g. maps, pictures, charts, models) … the teacher uses <German / Italian> when we do not understand … I can use <German / Italian> when I need to
Anxiety and Enjoyment of the CLIL Science Classroom /TOSRA and Foreign Language Classroom Anxiety Scale	… I feel tense when I speak in English … I worry when I hear new or unfamiliar words … I worry about making mistakes The class moves so quickly I worry about getting left behind I would enjoy science more if the lessons were in <Italian/German> I would understand science more if the lessons were in <Italian/German>
How difficult? /new **or: Perceptions of task demands when learning science in English** "*Rate how easy or difficult it is to …*" (Very difficult, Difficult, Neutral, Easy, Very Easy)	Learn technical words Ask questions Answer questions Discuss Take notes Write about science Read English textbooks Understand teacher's explanations Understand science concepts and ideas Work in small groups Do practical work (laboratories) Cope with the pace of the lesson Stay focused Remember things

Appendix D - Classroom Activities Timelines

Each timeline illustrates a 50-minutes class period. The class period is identified with a code as the following example: CS1-10B-1a, where the first two capital letters and the number indicate the case study (CS1, CS2 and CS3), the following number indicate the class year (10 or 11), the letter, just after the number, if present, indicates the section of the class (e.g. A or B). The next number identifies which lesson period does the transcript refer to (1 to 4). When the number is accompanied by a small letter (a or b) it means that the transcript refers to a double lesson, i.e. two units (a and b) of 50 minutes each on the same day.

Types of interactions are indicated as the following:

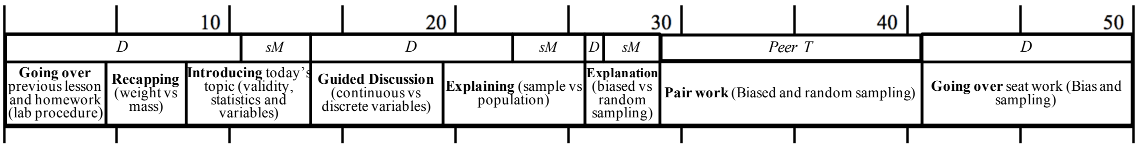
D = classroom dialogue (mostly Triadic Dialogues, but also Student-Questioning Dialogues, Teacher-Student Dialogues, and Cross-discussions)

sM = short monologue, i.e. uninterrupted lectures of a minimum duration of 2 minutes and shorter than five minute.

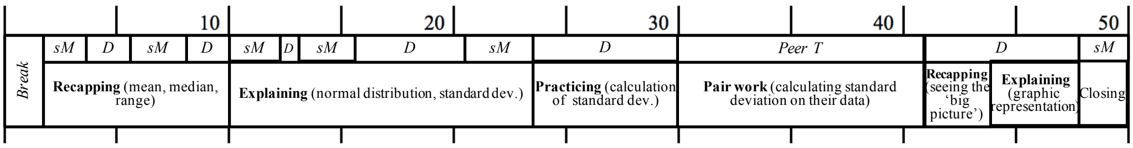
Peer T = peer talk, or student-to-student talk

Case Study 1 (CS1) Activities Timelines:

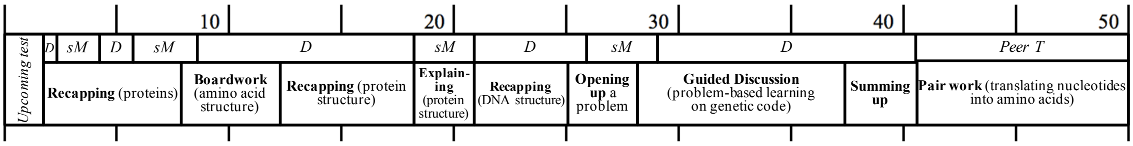
CS1-11-1a
30/11
(statistics)

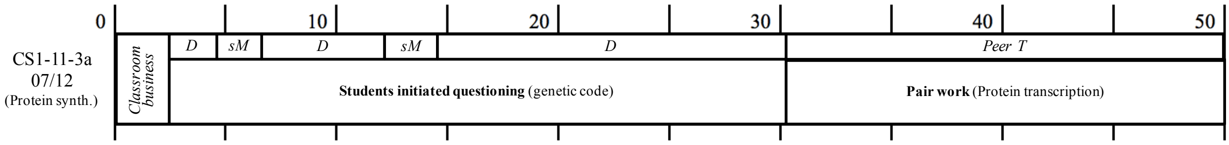


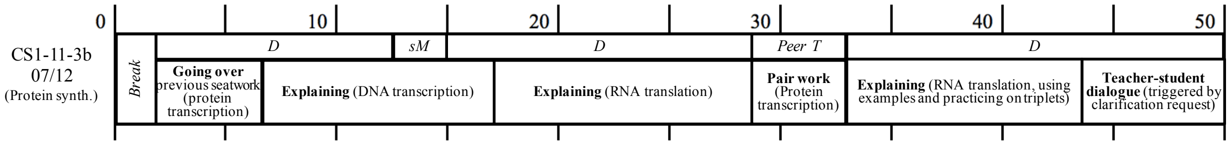
CS1-11-1b
30/11
(statistics)

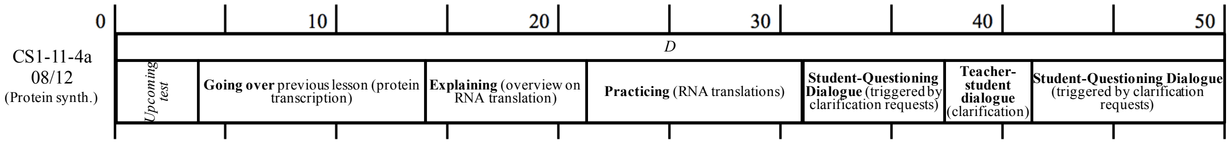


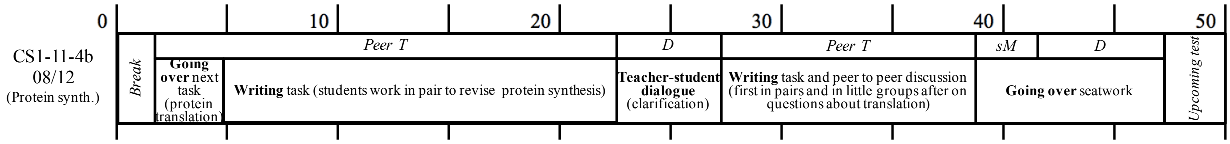
CS1-11-2
01/12
(Protein synth.)

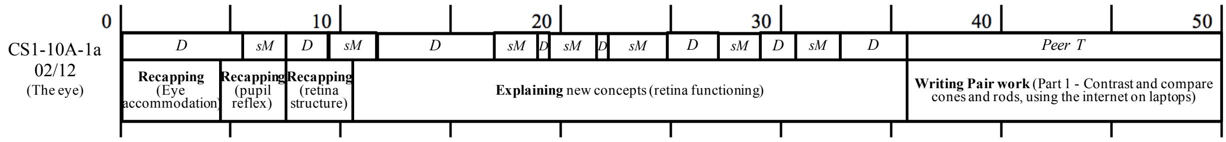


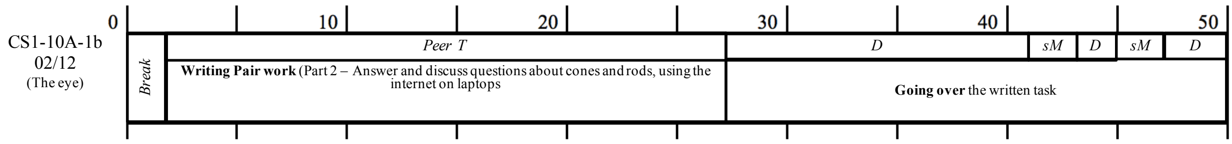

0
10
20
30
40
50
CS1-11-3a
07/12
(Protein synth.)
D
sM
D
sM
D
Peer T
Classroom business
Students initiated questioning (genetic code)
Pair work (Protein transcription)

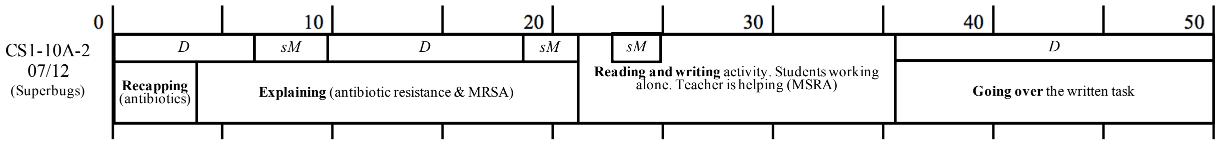

0
10
20
30
40
50
CS1-11-3b
07/12
(Protein synth.)
D
sM
D
Peer T
D
Break
Going over previous seatwork (protein transcription)
Explaining (DNA transcription)
Explaining (RNA translation)
Pair work (Protein transcription)
Explaining (RNA translation, using examples and practicing on triplets)
Teacher-student dialogue (triggered by clarification request)

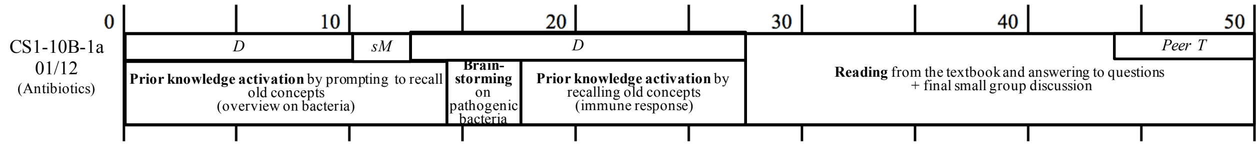

0
10
20
30
40
50
CS1-11-4a
08/12
(Protein synth.)
D
Upcoming test
Going over previous lesson (protein transcription)
Explaining (overview on RNA translation)
Practicing (RNA translations)
Student-Questioning Dialogue (triggered by clarification requests)
Teacher-student dialogue (clarification)
Student-Questioning Dialogue (triggered by clarification requests)

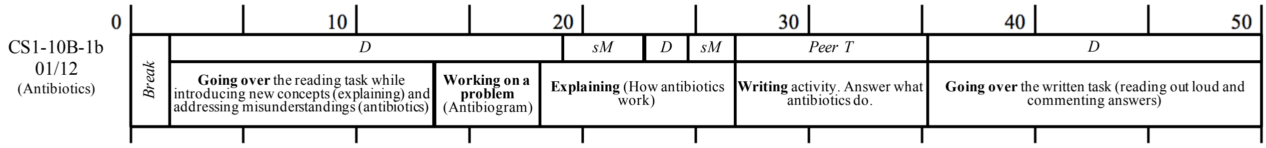

0
10
20
30
40
50
CS1-11-4b
08/12
(Protein synth.)
Peer T
D
Peer T
sM
D
Break
Going over next task (protein translation)
Writing task (students work in pair to revise protein synthesis)
Teacher-student dialogue (clarification)
Writing task and peer to peer discussion (first in pairs and in little groups after on questions about translation)
Going over seatwork
Upcoming test

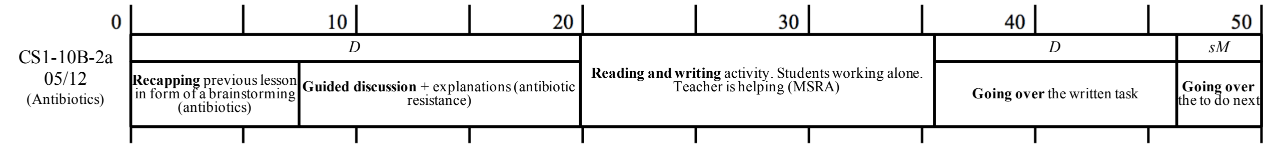

0
10
20
30
40
50
CS1-10A-1a
02/12
(The eye)
D
sM
D
sM
D
sM
D
sM
D
sM
D
sM
D
sM
D
Peer T
Recapping (Eye accommodation)
Recapping (pupil reflex)
Recapping (retina structure)
Explaining new concepts (retina functioning)
Writing Pair work (Part 1 - Contrast and compare cones and rods, using the internet on laptops)

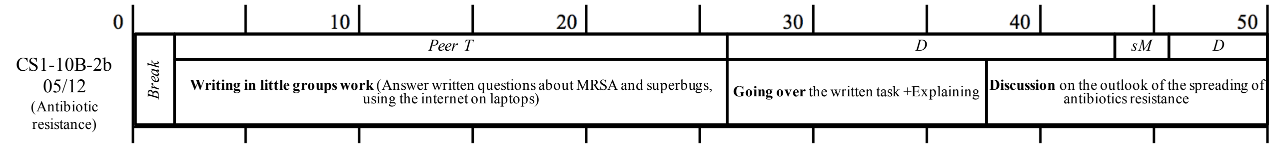

0
10
20
30
40
50
CS1-10A-1b
02/12
(The eye)
Peer T
D
sM
D
sM
D
Break
Writing Pair work (Part 2 – Answer and discuss questions about cones and rods, using the internet on laptops
Going over the written task

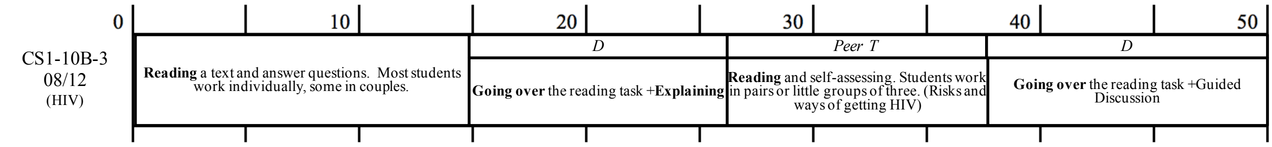

0
10
20
30
40
50
CS1-10A-2
07/12
(Superbugs)
D
sM
D
sM
sM
D
Recapping (antibiotics)
Explaining (antibiotic resistance & MRSA)
Reading and writing activity. Students working alone. Teacher is helping (MSRA)
Going over the written task


0
10
20
30
40
50
CS1-10B-1a
01/12
(Antibiotics)
D
sM
D
Peer T
Prior knowledge activation by prompting to recall old concepts (overview on bacteria)
Brain-storming on pathogenic bacteria
Prior knowledge activation by recalling old concepts (immune response)
Reading from the textbook and answering to questions + final small group discussion

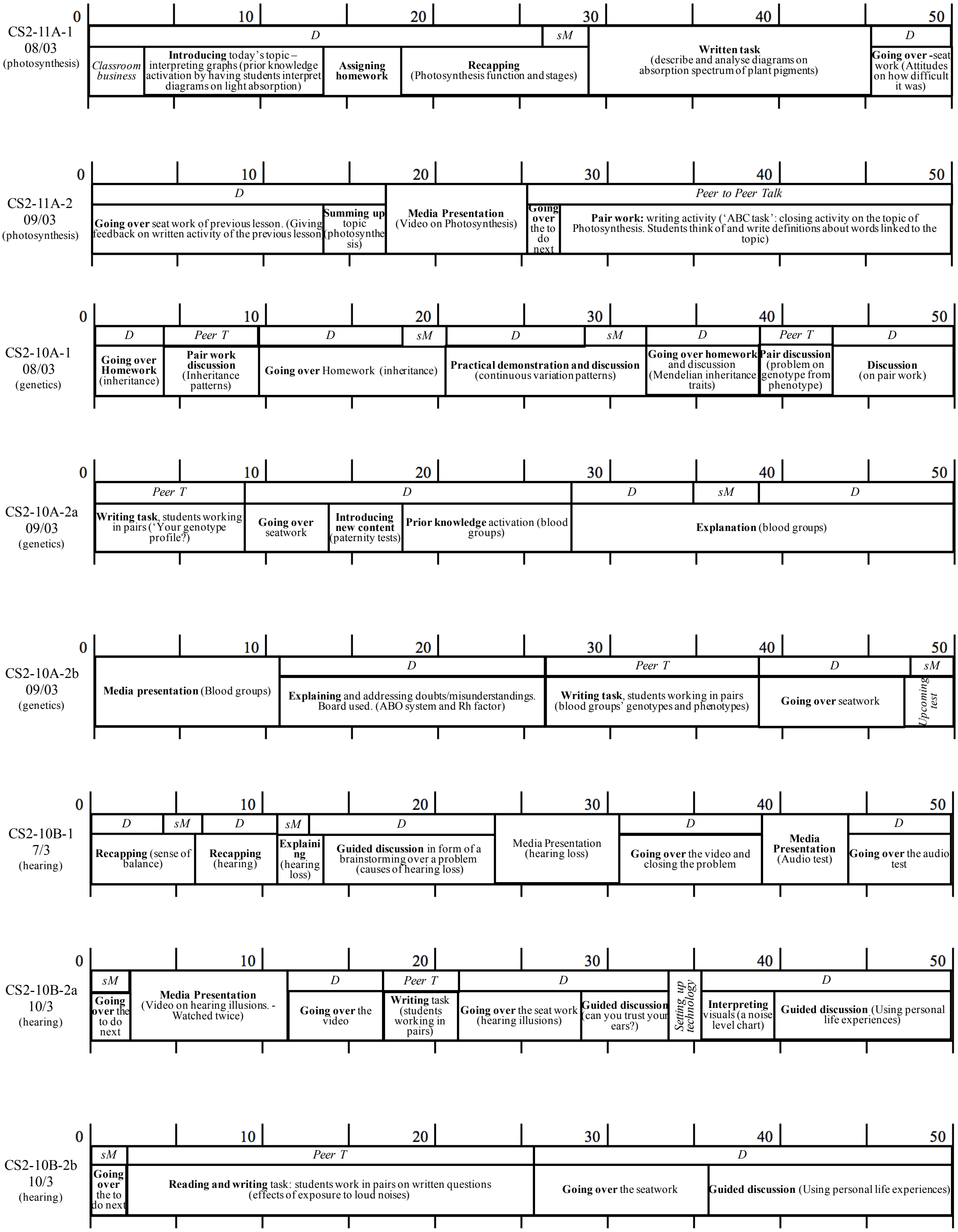

0
10
20
30
40
50
CS1-10B-1b
01/12
(Antibiotics)
Break
D
sM
D
sM
Peer T
D
Going over the reading task while introducing new concepts (explaining) and addressing misunderstandings (antibiotics)
Working on a problem (Antibiogram)
Explaining (How antibiotics work)
Writing activity. Answer what antibiotics do.
Going over the written task (reading out loud and commenting answers)


0
10
20
30
40
50
CS1-10B-2a
05/12
(Antibiotics)
D
D
sM
Recapping previous lesson in form of a brainstorming (antibiotics)
Guided discussion + explanations (antibiotic resistance)
Reading and writing activity. Students working alone. Teacher is helping (MSRA)
Going over the written task
Going over the to do next

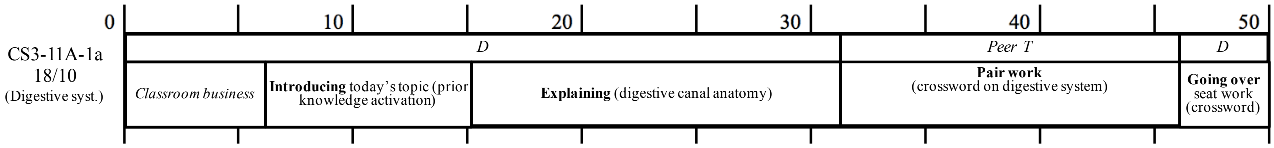

0
10
20
30
40
50
CS1-10B-2b
05/12
(Antibiotic resistance)
Break
Peer T
D
sM
D
Writing in little groups work (Answer written questions about MRSA and superbugs, using the internet on laptops)
Going over the written task +Explaining
Discussion on the outlook of the spreading of antibiotics resistance

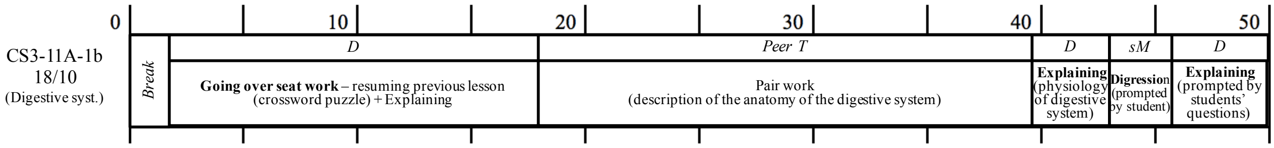

0
10
20
30
40
50
CS1-10B-3
08/12
(HIV)
D
Peer T
D
Reading a text and answer questions. Most students work individually, some in couples.
Going over the reading task +**Explaining**
Reading and self-assessing. Students work in pairs or little groups of three. (Risks and ways of getting HIV)
Going over the reading task +Guided Discussion

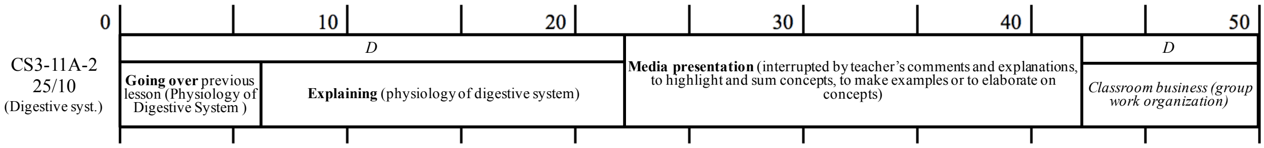
Case Study 2 (CS2) Activities Timelines:

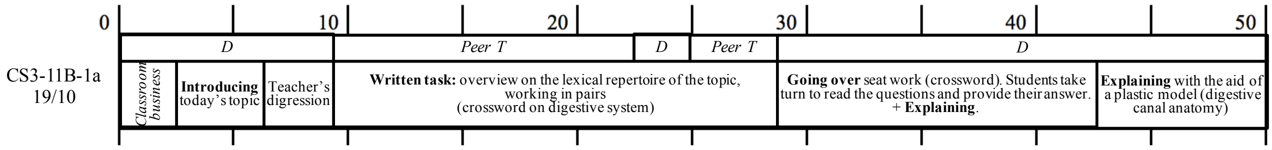


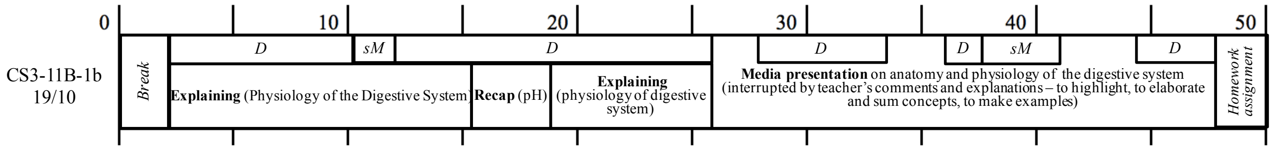
Case Study 3 (CS3) Activities Timelines:

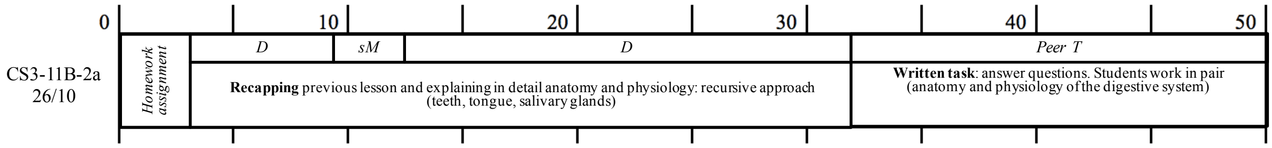


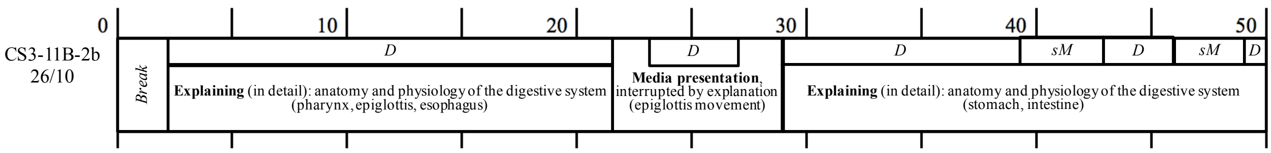












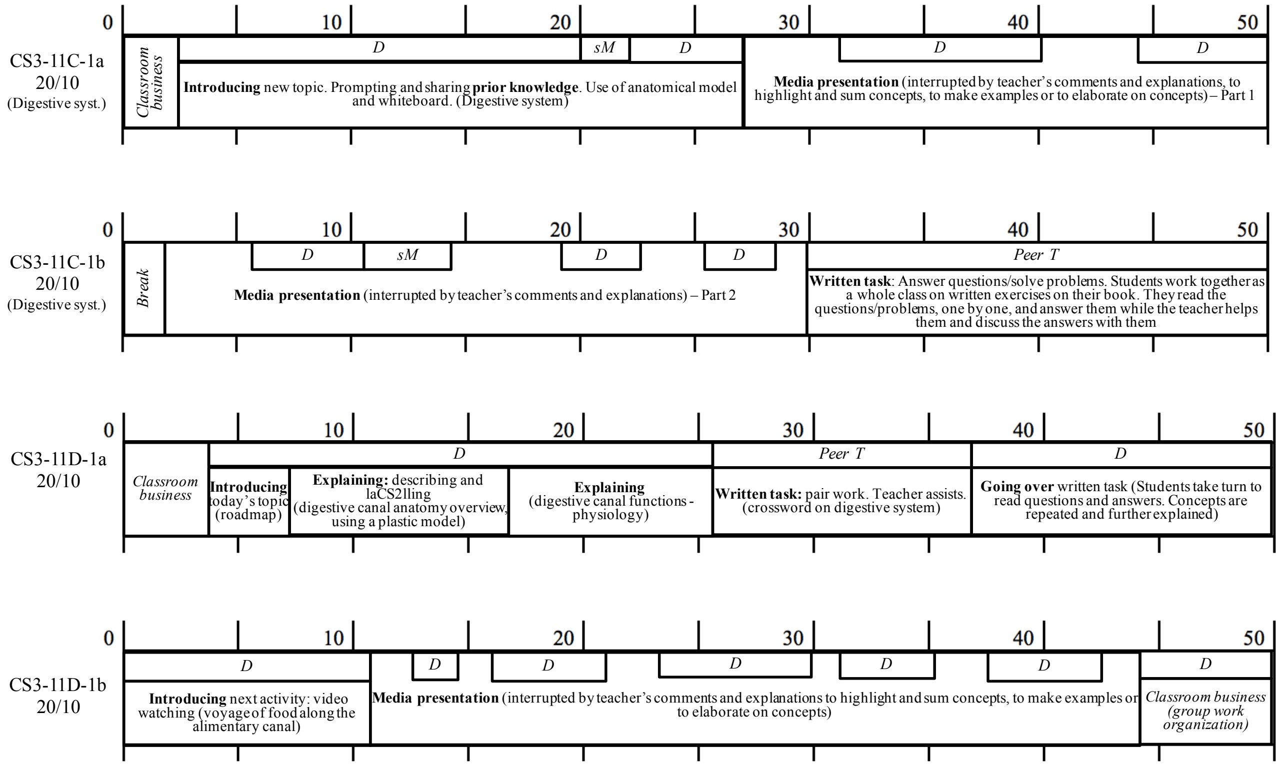
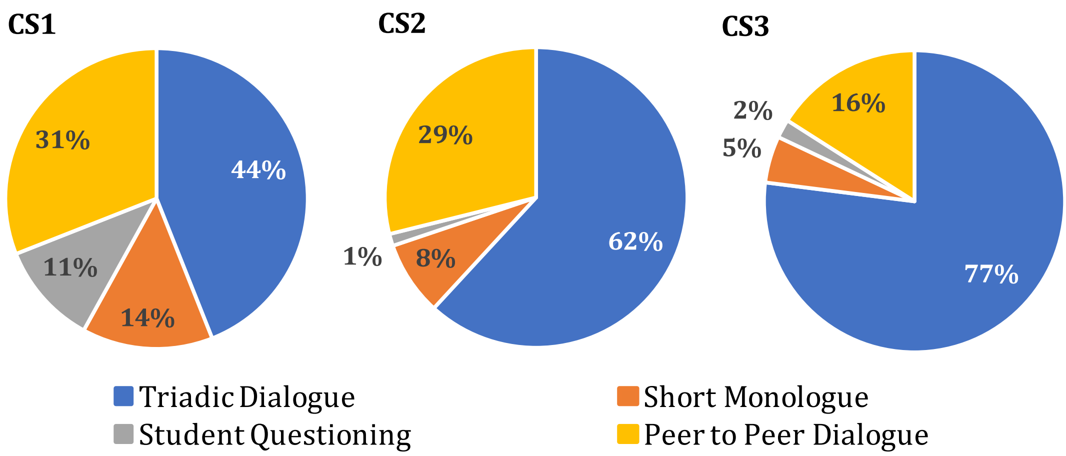


Figure D.1 Coverage percentages of the main types of talk across the three case studies calculated from coverage data provided by the NVivo software.



NOTE: The comparison needs to be treated carefully as the lessons across case studies where not homogeneous in terms of topics covered, teachers' purposes, classroom settings, activities performed.

Appendix E – Categories, Codes and Frequency in the Interactions Analysis of Classroom Discourse

Table E.1 Categories and codes emerged from classroom discourse analysis.

Components	Categories	Codes
Teacher questions	**LOT (Low Order Thinking) questions**	Recall Questions (Who remembers?) Recognising and Describing Guess What Teacher Thinks Prior knowledge questions (What do you know already?)
	HOT (High Order Thinking) questions	
	Language-related questions	Parlance Questions Checking lexical understanding
	Questioning strategies	Contingent questioning: Extending (What else?) Probing (Why so?) Constructive challenge (Are you sure?) Giving clues and cues Wait time Rephrasing
	Feedback strategies (upon correct answers)	Affirmation-cum-Direct-Instruction Restating Reformulating
	(upon incorrect or incomplete answer)	Explicit correction Clarifying Filling the gaps Neutral feedback
Students' Answers	**Cognitive level of engagement**	Declarative knowledge Schematic knowledge Strategic knowledge
	Students' answering strategies	Being cautious Being hesitant Choral answer Circumlocution Using examples "fill-in-the-blank" answer
	Students' verbal production	One-word (or short expression) answer Extended response
Students' Questions	**Wonderment questions:**	Asking for clarification Deeper understanding Non-task curiosity
	Basic information questions:	Asking for explanation, example Asking for lexical meaning Asking for repetition Asking for information Asking for confirmation Asking for procedures

Appendix F – Ethics

Teacher's Information Sheet

OÉ Gaillimh
NUI Galway

Project title:

"The Bilingual Science Classroom: Learning Science when the Language of Instruction is a Foreign Language - A Transnational Multiple Case Study"

Aims and purpose of this research

This study investigates the impact of using a bilingual approach for teaching and learning science, biology in particular, at a secondary level of instruction, through the medium of English. In particular, it explores how opportunities for learning science can be facilitated when a bilingual approach is implemented science classes. The research involves studying and comparing three secondary school settings (Germany and Italy).

Why is this research important?

Studying a non-linguistic discipline in a foreign language is often referred as a "two for one" approach, because learners in this programme learn subject matter and the foreign language at the same time. However, students sometimes struggle to cope with the difficulty of learning what is often perceived as a difficult topic in a foreign language. The findings of this research are meant to shed light on how it is possible to overcome this layering of difficulties and to capitalize on all the resources that Bilingual students and teacher bring to the science learning. We hope that this study will help the school community to learn to perceive the languages (the more the better) as resources when it comes to study science.

What will you be asked to do and what is involved in data collection?

You will be central to the implementation of the research project and it is of importance that you agree to participate freely and willingly. The researcher will seek suggestions from the teacher to minimize the nuisance of having the researcher in class, according to the learning needs of the class.

The methods for collecting data will mainly consist of direct observations of your science classrooms. The researcher will observe the lessons without participating and acting as less intrusively as possible. Contents, goals and activities of the lessons are at your total discretion and the researcher respects your distinctive beliefs and teaching styles. The observations will last approximately for two weeks and will be repeated twice over at least four months (a total of no more than four weeks). During the observations, the researcher will take notes on what the learners and their teacher do and say. Part of the lessons will be audio-recorded. The recordings will be transcribed and anonymized using pseudonyms. These observations will be presumably repeated twice over a period of at least four months. The second set of observations depends on the results of the first period of observation. The researcher will understandably need to maximize the number of observations in the agreed time frame, and will attempt to observe the highest possible number of lessons. However, the researcher respects your professional and personal agendas, and she will do her best to be flexible, to adapt to your needs and to face unexpected events and interruptions, which are an inevitable part of the school routine.

The second source of data will be a questionnaire filled in by the students. This will be anonymous and intended to investigate students' perceptions of the classroom environment (15 minutes, during the school time). Finally, a brief, informal, one-on-one interview with you will complete the observations. During this you will be asked to share your beliefs and perceptions about your experience with the bilingual approach. If you agree to it, the interview will be audiotaped. This will allow the researcher a more accurate recording of the details. The transcript of the interview with you will be sent to you for editing and approval before being published.

If you decide to participate, you will return the following signed form to me by post or by email.

1

Possible benefits from this research

It is important to point out that there aren't direct benefits for you in partaking to this study. Nevertheless, you will have the opportunity to make your voice heard and to contribute to the improvement of the teaching of science in a linguistically diverse classroom.

Your rights within this study

You have the right to completely voluntary participation. You have the right to have the audio recorder turned off during the interview. You may also withdraw from this study at any time with no penalty. If you decide to withdraw from the study at any time, please contact me.

Data Protection

Your name and address will be collected and only used to contact you with the follow-up of the research. For instance, for sending you the transcripts of the parts of the interviews that are meant to be published in order to be edited and approved.

Both you and your students' confidentiality will be completely protected and neither you nor your students will be identifiable in any published report. Transcripts of the classroom audio-recording will be anonymized by using pseudonyms. Audio recordings of the classroom's interactions will be destroyed as soon as the transcriptions have been produced and cross-checked with the field notes. The interview with you will be audio-taped and transcribed and your true identity will be protected in same way as outlined above for the other transcripts. When the study is completed, the retained written data will be securely stored at the NUIG for five years, in line with the University Data Retention Policy. These data will be used solely for the purposes of the research project (including dissemination of findings). No-one other than research colleagues, supervisors or examiners will have access to any of the data collected. The findings of this research study will all converge into a PhD dissertation. It is also likely that articles for research journals based on this research will be published.

If you have any questions

If you have any questions or concerns about any aspect of this study, please feel free to contact the me, Laura Tagnin, at l.tagnin1@nuigalway.ie or at +39 347 1593564. Alternatively, you may contact my supervisor, Dr. Máire Ní Ríordain by email at maire.niriordain@ccu.ie.

Thank you for taking the time to read this information sheet.

Sincerely,

Laura Tagnin

"The CLIL Science Classroom: Learning Science when the Language of Instruction is a Foreign Language - A Transnational Multiple Case Study"

Teacher Assent Form

I ____ agree to take part in this study.
(name, surname).

For follow-up I want to be contacted at this address (email or mail):

____

In addition,

1. I confirm that I have read through and understood the information sheet.
2. I was provided with contact details for the researcher of this study and was encouraged to ask any questions I may have.
3. My participation in this study is completely voluntary.
4. I understand that I may stop participating in this study at any time.
5. I understand that I may stop participating in this study at any time.
6. I agree for the classroom talks to be audio recorded.
7. I agree for a personal interview to be audio recorded.

Signature of participant: ____ Date: _____________

Signature of researcher: ____ Date: _____________

Student Information Sheet

The CLIL Science Classroom: Learning Science when the Language of Instruction is a Foreign Language

Adolescent Participant Information Sheet

Please read over the following document in detail as it outlines all of the information you need to know about this study and what will be expected of you as a participant.

Aims and purpose of this research

The purpose of this research is to understand how the use of a foreign language impacts on the learning of Science. In particular, it will be investigated how everyday school strategies can help you and your teacher to powerfully use all the resources available (e.g. what you bring from outside the school, English AND *German/Italian*) to study science and how you feel about not using *German/Italian* for learning science.

Why is this research important?

The findings of this research are meant to shed light on how can the use of a foreign language best facilitate the learning of science. This may improve the practices in the CLIL classroom and help future learners. You will not be the only sample of students in this research. Other three classes of your same grade will be investigated in the same way as you, two in Italy, two in Germany.

What will you be asked to do?

You will be asked to tolerate the presence of a researcher in your classroom during your Science lessons for a period of two weeks, twice. The researcher will observe what you, your classmates and your teacher do and say. Sometimes parts of the lessons will be audio-recorded. The researcher will do her best not to disrupt your classes and you will do your best to ignore her. This doesn't seem much now, but it is the most difficult thing to achieve in a research like this. Secondly you will be asked to complete an anonymous questionnaire (30-35 minutes), about what you think on this learning methodology.

What will you be asked about?

In the questionnaire you will be asked about a number of things related to your own background about learning English, science and about what you think, and how you feel about learning Science through English.
If there are any questions you do not want to answer, that is completely fine, and you will just need to skip those questions.

Possible benefits of participating in this study
It is important to point out that there aren't direct benefits for you in partaking to this study.
It is also very important to understand that your participation in the research will in no way, negatively or positively, affect your school performance. In the same way, if you decide not to participate, you will be not discriminated and there will be no negative consequences.

Risks

There are no known risks in participating in this study. If you would prefer not to answer specific questions in the questionnaire you can just skip them. Your questionnaire will still be returned to the researcher even if incomplete, no one will know that you didn't complete it and there will be no negative consequences. Please be reassured that the filling in will always remain completely anonymous.
During the observations, parts of the lessons may be audiotaped for keeping up with the classroom interactions when taking notes may be not enough. Notes taken during observations and transcriptions will be handled as confidentially as possible and your name and any other personally identifiable information will never be used. The data protection measures are described below. However, if for some reason participating in the study makes you feel uncomfortable, you can stop participating at any time. Please let me know immediately by emailing the researcher at l.tagnin1@nuigalway.ie, stating "withdraw". At that point you will not be asked to fill in the questionnaire and no data will be specifically collected relating to you during the observations, but you will still have to attend your regular lessons.

Your rights in this study

- You have the right to completely voluntary participation.

- You have the right to decide not to participate at any time, with no negative consequences. In this case, no data will be specifically collected relating to you during the observations, but you will still have to attend your regular lessons.
- You have the right not to answer any question of the questionnaire, and you do not need to explain why.
- You have the right to withdraw from the study at any time by emailing the researcher at l.tagnin1@nuigalway.ie, stating "withdraw".

Confidentiality

Your confidentiality will be completely protected in this study. When you decide to participate, you will hand your form in to your teacher in a sealed envelope, so no one will know if the form inside says that you do or don't want to participate. Alternatively, you can contact me directly, instead of handing in the sealed envelope at school.

If you decide to participate you will be asked to fill in a questionnaire during a school time that will be agreed with your teacher. You will not be asked to write your name on the questionnaire, so that the researcher cannot identify you and any results will remain completely anonymous.

When I write the final report, if there are any details that could identify you in the data, I will change them so that no one can tell who you are. A false name (called a 'pseudonym') will be used on the transcripts of the classroom talks and in all related files to protect your identity.

What will happen to the results and findings of this study?

At the end of this research study, I will write a large report called a Thesis. You will be sent a copy of this thesis if you wish. It is also likely that I will write articles for research journals based off of this research.

What should you do if you have any questions?
If you have any questions or concerns at all about any aspect of this study or your participation in it, please feel free to contact the researcher, Laura Tagnin, at l.tagnin1@nuigalway.ie or at +353 85 8376858. Alternatively, you may contact my supervisor, Dr. Máire Ní Ríordain by email at maire.niriordain@nuigalway.ie.

Thank you for taking the time to thoughtfully read this information sheet.

Sincerely,
Laura Tagnin
Principal Researcher

Student Assent/Consent Form

Adolescent Assent/Consent Form

Title of Project: *The CLIL Science Classroom: Learning Science when the Language of Instruction is a Foreign Language - A Transnational Multiple Case Study.*
Name of Researcher: Laura Tagnin

Declaration:

I ___________________________ (adolescent participant's name) agree that the following is true:

Please tick as appropriate:

1. As a participant in this study, I confirm that I have read through the information sheet.
   [YES] [NO]
2. As a participant in this study, I do understand the information contained in the information sheet and I have had enough time to consider whether or not I want to participate in this study.
   [YES] [NO]

3. I was provided with contact details for the researcher of this study and was encouraged to ask any questions I may have.
   [YES] [NO]

4. My participation in this study is completely voluntary.
   [YES] [NO]

5. I understand that I may stop participating in this study at any time.
   [YES] [NO]

6. I agree to take part in this study which involves the completion of a questionnaire and being observed during the normal activities in my classroom.
   [YES] [NO]

7. I agree that that some parts of the classroom talk will be audio-recorded, and that the recordings will be destroyed as soon as they will be transcribed.
   [YES] [NO]

8. I agree that the transcripts of the classroom talk, survey notes and the questionnaires will be kept in a locked drawer at the National University of Galway, Ireland, for a period of 5 years after the completion of this study.
   [YES] [NO]

Signature of adolescent participant: ___________________ Date: ____________

Signature of parent/guardian: ________________________ Date: ____________

Signature of researcher: ____________________________ Date: ____________