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„Classroom discourse in CLIL mathematics classes: the use of cognitive discourse functions“


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# 1. Introduction

In response to the growing necessity in modern society to be able to communicate with people from all over the world as well as the emergence of English as the main language of communication internationally, educational institutions have sought to develop new pedagogical practices to promote the learning of foreign languages. In this context, one approach has been to integrate the learning of a foreign language into content-driven subjects. Immersion programmes, first introduced in Canada in the 1960s, in which students whose first language was English were taught a variety of subjects in French, are regarded as the first widespread implementation of such a dual-lingual policy. In Europe, the term content and language integrated learning (CLIL), was coined in the 1990s to create a framework for a pedagogical approach of this nature specific to the unique demographic and cultural factors found in the European context.

The essence of CLIL is that there is an explicit focus on both content and language in the learning process, so students acquire the relevant subject knowledge while simultaneously developing their language skills. However, in practice, CLIL programmes are often organised around the teaching of the content subjects: "CLIL lessons are timetabled as content-lessons, taught by specialist teachers of those subjects through the medium of English, and follow the national curriculum of the content subject" (Dalton-Puffer 2013: 219). This means that the reality of CLIL is very often that it is simply a content subject taught in a different language without an explicit focus on language teaching, which does not reflect the original purpose of the approach. A main cause for this discrepancy is that at present there is no practical construct available to investigate the integration of content and language in CLIL classrooms. This has led to a gap in research, as studies have focused predominantly on either content or language in isolation. Furthermore, there has also been no viable practical framework available to practitioners of CLIL, which means that teachers are largely individually responsible for finding means to integrate content and language in their own classrooms.

In response to these circumstances, Dalton-Puffer (2013) developed the construct of cognitive discourse functions (CDFs), which aims to link the cognitive thinking processes occurring in content subjects with their corresponding verbalisations in language. The framework can function as a theoretical tool to empirically analyse the integration of content and language in naturalistic CLIL classroom. Additionally, these results can then be used to identify connections between areas of knowledge in certain subjects and corresponding linguistic competences, which can in turn create a foundation for the formulation of subject-specific CLIL curricula. Indeed, previous studies of CDFs in physics (Kröss 2011), biology (Hopf & Hofmann 2015), and economics (Brückl 2016) have shown promising results, and this thesis aims to build on this body of research.

In this view, the thesis has two main goals. Firstly, it intends to build on research of the CDF construct presented by previous studies, so it can be further empirically validated. Secondly, this text will provide insight into the relationship between language and content in the subject of mathematics, so the results can be used to inform the formulation of specific language learning objectives in CLIL mathematics classrooms. To this end, this thesis will first present a general discussion of the CLIL approach as well as a characterisation of the subject of mathematics. Then the CDF construct will be described in detail as the underlying framework for the analysis. Finally, the thesis will outline the results of the analysis of the use of CDFs in the recordings of seven naturalistic CLIL mathematics classes. In this regard, it is the hope of the author that the results of this thesis will provide a general direction for future work on the actual integration of content and language in CLIL in mathematics class.

# 2. Introducing CLIL: an outline

This thesis aims to provide greater insight into the classroom discourse of CLIL mathematics classes, and consequently, a general outline of CLIL is necessary. The following chapter gives as an extensive introduction to CLIL, looking back at its origins as well as providing an overview of empirical findings so as to locate the focus of this thesis in the broad field of CLIL research.

## 2.1. An early model of bilingual education - Immersion

Teaching and learning content in a foreign language is certainly not a new phenomenon, and numerous authors have pointed out historical tendencies of using a non-native language as the medium of instruction in teaching. Mehisto, Marsh and Frigols (2008: 9), for instance, refer to the Akkadians, a civilisation living in the modern-day Iraq area approximately 5000 years ago, who, upon conquering the Sumerians, had their scholars teach them various subjects in Sumerian with the aim of better learning the language. Coyle, Hood, and Marsh (2010: 2) allude to education in the Roman Empire, in which children were educated in Greek in order to provide them better opportunities in adulthood. These examples indicate that the foundation of content and language integrated learning has a long history, but they also illustrate that the initiatives for using a foreign language for instruction are strongly affected by political, geographic, and demographic contexts.

A more contemporary context for the implementation of a bilingual educational practice is given in Canada. While until the 1950s English was principally used in politics, business, and law in Canada, the Official Languages Act of 1969 proclaimed French and English as the official languages of the country (*The Canada Guide*). The seeds for this development originated in the region of Quebec, in which French was the dominant language spoken by most of its inhabitants. The English-speaking population of Quebec recognized in the 1960s that "economic survival there would require high levels of proficiency in French" (Swain & Johnson 1997: 2). Furthermore, parents of students realized that conventional language teaching in French was proving unsuccessful, and they advocated strongly for improvements to the prevailing programme, which ultimately led to the adoption of a dual-language approach named immersion in which students were taught in both English and French albeit to varying degrees in different contexts (Swain & Johnson 1997: 2-3).

The main idea of immersion was and still is that, in content subjects, students are educated not only in English, their native language, but also in French, the official language of Quebec. Consequently, the greater exposure to the second language, French, should lead to greater proficiency. While implementations of immersion differ according to contextual factors, Swain and Johnson identify eight "core features of a prototypical immersion program" (1997: 6-8):

1. The L2 is a medium of instruction.
2. The immersion curriculum parallels the local L1 curriculum.

3. Overt support exists for the L1.
4. The program 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.

This characterisation of immersion indicates that students are expected to learn the same content as if the course were taught in their L1 (2. feature), and furthermore that teachers of immersion programmes must be bilingual (feature 7).

Swain and Johnson's list (1997: 6-8) provides a useful overview of typical features of immersion in the 1990s. However, the late 20th and early 21st century have been characterized by increasing multiculturism as well as multilingualism, and this dynamic nature of society affects the validity of this depiction of immersion. This is emphasized in Swain and Lapkin's (2005) revision of the features, in which they suggest changes to five of the eight characteristics. The adapted model reflects the diverse nature of the modern-day classrooms, in which students have a diverse variety of native languages. For instance, the first core feature, "The L2 is a medium of instruction", is changed to "The immersion language is the medium of instruction" (2005: 172). In making this adaptation, the authors acknowledge that for some students the immersion language may be the third of even fourth language. The development of this characterization serves as an example that language classrooms are strongly affected by the linguistic and cultural backgrounds of the participating students (and teachers) and, as such, are constantly evolving and changing.

Immersion education is considered an important antecedent of content and language integrated learning (CLIL). This is of particular importance because, while CLIL is relatively new in the academic field of bilingual education and consequently not backed by long-term empirical studies, immersion has been the subject of research since the 1960s. In their article highlighting differences between CLIL and immersion, Lasagabaster and Sierra note that "immersion programmes have been in force for more than two decades and can rely on a significant amount of research into both their linguistic and non-linguistic effects" (2010: 373). Furthermore, Marsh highlights that this has led to the accumulation of a "large amount of research carried out to validate good practice and identify malfunction." (2002: 56). In consequence, immersion can be characterized as a well-researched, successful model of bilingual education.

## 2.2. Bilingual education in Europe – the birth of CLIL

The European continent has a longstanding history of bilingual education. In his landmark publication *CLIL/EMILE – The European Dimension*, Marsh comments that “Teaching and learning through a foreign language has a long tradition in Europe particularly in border regions and certain types of selective school or college” (2002: 50). While teaching through the medium of a foreign language has long been present in European society, formal dual-language programmes which are also accessible to a large portion of the population are a much more recent phenomenon.

An explicit focus on language learning within the European Union can be traced to the Education Council Resolution of 1976, which on language learning states the objective of “offering all pupils the opportunity of learning at least one other Community language” (Council of Europe 1976). In the 1990s, the European Union reformulated this goal to add a further language: “it is becoming necessary for everyone, irrespective of training and education routes chosen, to be able to acquire and keep up their ability to communicate in at least two Community languages in addition to their mother tongue.” (Council of Europe 1996: 47). The European Council Resolution of 1995 also states that aim of exploring new methodologies in language teaching, referring explicitly to the aim of introduction of “the teaching of classes in a foreign language for disciplines other than languages, providing bilingual teaching.” (Council of Europe 1995). These circumstances in the 1990s provided the foundation for the development of a new approach to integrating language and content, and Marsh confirms this arguing that “the 1990s was the decade in which *teaching and learning through a foreign language* was increasingly adopted as a platform for providing the sought for *extra means of language teaching and learning delivery*” (2002: 54).

The European Union’s clear ambition to develop language proficiency among its member states provided the incentive to search for an applicable model of bilingual education. Given that at this time immersion programmes had been implemented for approximately thirty years and also backed with a corresponding body of research, it seems that an obvious solution would have been to adopt immersion in the European setting. Indeed, Swain and Johnson argue that “immersion” can be used as an umbrella term and claim that “‘immersion education’ can be legitimately and usefully applied beyond its purely historical origins in Canada to a wide range of programs despite differences in their aims, socioeconomic contexts, and manner of implementation” (1997: 1). However, immersion did not establish itself in the European context, and Coyle names three main reasons for this rejection (2007: 544-545):

1. Immersion was already heavily associated with the cultural and linguistic factors of the Canadian context, which were very different to the diverse circumstances and needs across Europe. This argument is reiterated by Marsh, who states that “Recognition that Europe is not Canada, not as a whole, or even in terms of most regions, led to a seeking out for alternative terms” (2002: 57).

2. Bilingual programmes across Europe were diverse with different motives and goals. There was a general consensus that a new term was required to reflect this reality of "[o]ne size does not fit all" (Coyle 2007: 545)
3. As newer approaches and methodologies were emerging in the 1990s, experts in the field of language teaching and bilingual education pushed for new terminology to incorporate these developments.

These different factors led to the adoption of the umbrella term content and language integrated learning, in short CLIL, to describe "any activity in which a foreign language is used as a tool in the learning of a non-language subject in which both language and the subject have a joint curricular role" (Marsh 2002: 58).

It is evident that the circumstances of the 1990s were ideal for the introduction of a new approach to describe an inclusive, dual-focused approach to teaching both language and content. The immediate success of CLIL is illustrated by the fact that in "the late 1990s, usage of the term soared as can be seen from publication references and internet site usage" (Marsh 2002: 58). This positive development continued into the 21st century, and in a more recent publication, Hüttner and Smit write that "CLIL (Content-and-Language-Integrated-Learning) has enjoyed massive uptake in continental Europe over the last twenty years in very diverse educational settings and has given rise to a vibrant research scene" (2013: 160). Today, CLIL programmes have been implemented in a great variety of setting across Europe and there is also a great body of research investigating a number of different aspects of the approach.

## 2.3. A definition of CLIL

In order to adequately organize research on CLIL, it is first necessary to provide a concise definition of the approach. Coyle, Hood, and Marsh, in their important work outlining CLIL, describe it as follows (2010: 1):

> Content and Language Integrated Learning (CLIL) is a dual-focused educational approach in which an **additional language** is used for the learning and teaching of both content *and* language. That is, in the teaching and learning process, there is a focus not only on content, and not only on language. Each is interwoven, even if the emphasis is greater on one or the other at a given time.

Upon first impression, this may seem to be a sufficiently accurate description of CLIL; however, there is even today a continuing debate among academics over a precise definition of the approach. Indeed, Perez-Canado refers to this dispute, stating that an "initial controversy which is affecting CLIL pertains to its very characterization" (2016: 11), and Bruton also comments on the matter, referring to "the surprisingly unresolved issue of what CLIL actually is" (2015: 120).

As mentioned in the previous section, Coyle states one of the reasons for adopting new terminology to describe the integration of language and content in teaching to be to reflect the "diverse origins and varied purposes of different bilingual programmes across Europe" (2007: 545). Out of necessity, a corresponding characterization of CLIL would have to be adequately inclusive, so the term can still be applied in describing dual-focused approaches in a wide range of different contexts. However, numerous academics have criticised this conception of CLIL as being vague and ill-defined. Bruton, a prominent critic of CLIL research, argues that "Local, contextual variation cannot be used as an excuse for not clarifying what CLIL is and what it is supposed to do" (2015: 126). Many researchers in the field take a similar perspective on the issue, criticizing the lack of clarity in the definition of CLIL (Bruton 2015; Cenoz, Genesee & Gorter 2014; Paran 2013; Broca 2016). Bruton (2017: 4) also notes that one of the major problems with a vague definition of the concept is that any studies of the implementation of CLIL differ strongly in contextual factors and consequently no generalisations can be made.

A further issue that arises with a general definition of CLIL is locating the concept with regard to other bilingual approaches, such as immersion or content-based instruction. Paran notes that CLIL "is afflicted with a high lack of terminological clarity, starting with the confusion between CLIL, CBI, and Immersion Education" (2013: 319). There have been a number of different attempts to clarify this linguistic puzzle with differing results. Coyle, for instance, maintains that CLIL is a unique pedagogical construct different from "bilingual or immersion education and a host of alternatives and variations such as content-based language teaching, English for Special Purposes, [and] plurilingual education" (2008: 97). Furthermore, while Lasagabaster and Sierra (2010) find some similarities between CLIL and immersion, they highlight differences in all of the following areas: language of instruction, teachers, starting age, teaching materials, language objective, immigrant students, and research. The authors emphasize that "there is a compelling need to distinguish between these two types of programme [immersion and CLIL] because [...] their differences are remarkable" (Lasagabaster and Sierra 2010: 373). Various publications reveal a trend to emphasize the differences between CLIL, immersion, and CBI, insisting that CLIL is fundamentally unique (see Perez-Canado 2012; Perez-Vidal 2013).

Numerous academics in the field take a contrasting position regarding the relationship of CLIL with other forms of multilingual education. In their critical evaluation of CLIL, Cenoz, Genesee and Gorter (2014) describe numerous overlaps between CLIL, immersion, and other forms of CBI. Furthermore, in his comparison of CBI and CLIL, Cenoz (2015) presents his methodical analysis of the two approaches with regards to medium of instruction, language aims, societal and educational aims, and typical type of child. He concludes that "there are no differences between CBI and CLIL regarding their essential properties" (Cenoz 2015: 21). Llinares takes a more pragmatic approach to the debate and explains that while immersion and CLIL may carry different associations and be implemented in different contexts, the integration of language and content is situated at the core of both concepts and consequently this should be the focus of research (2015: 59).

The pathway out of this terminological labyrinth seems to be to view CLIL as an overarching conceptual framework. Dalton-Puffer *et al.* highlight the problematic issues in attempting to identify CLIL or immersion as the correct term and maintain such discussions have "already proven to run in circles" (2014: 214). In this context, the perspective of CLIL as an umbrella term has become increasingly important and is widely accepted in the academic community (see Dalton-Puffer *et al.* 2014; Coyle 2007; Hüttner & Smit 2013; Hüttner 2017; Marsh 2002; Mehisto, Marsh & Frigols 2008). This means that CLIL can be used to describe "a variety of practices, which share some 'family resemblance' and are heavily influenced by contextual factors" (Hüttner 2017: 482). Furthermore, according to this definition, immersion can also be classified as a form CLIL (Cenoz, Genesee & Gorter 2014: 255). In this regard, CLIL acts as a unifying term, which be used as a generic label for different forms of multilingual education.

A view of CLIL in which it is understood as an umbrella term is particularly useful as it provides an overarching framework which unifies the diverse implementations of integration of language and content in teaching. The Eurydice report of 2006, *Content and Language Integrated Learning (CLIL) at School in Europe*, which describes differences in CLIL provisions across the European continent illustrates this fact. The survey outlines a variety of factors which vary in CLIL programmes in different countries, for instance the target language, levels of education at which CLIL is introduced, aims, admission criteria and official teaching time allocated to CLIL (Eurydice 2006). Furthermore, the document highlights the great diversity in implementation. Malta, for instance, uses the term "bilingual education" to describe CLIL programmes at primary level in mainstream education in which 50% of lessons are held in English, while in the French community in Belgium, the term "immersion" is used to describe CLIL programmes at pre-primary, primary, or secondary level with a target language of Dutch, German, or English (Eurydice 2006). These examples highlight that CLIL as an umbrella term fulfils its purpose of providing a unifying label for different varieties of CLIL in the European context.

This widely accepted overarching conception of CLIL encapsulates the variety of multilingual education; however, this understanding does not seem to resolve the problematic issue of CLIL being characterized as vague and ill-defined. Bruton, for instance, remains undeterred in his criticism of CLIL and insists that "for coherence, CLIL has to be clearly defined and demarcated from non-CLIL alternatives, in order to operationalise the concept for empirical research purposes of identification and comparison" (2017: 4). Some academics in the field have proposed possible models to bridge this gap in research. Cenoz, Genesee, and Gorter advocate for "establishing a taxonomy of different common forms of CLIL/CBI so as to circumscribe the diverse contexts in which CLIL is found" (2014: 258). Dalton-Puffer *et al.* take a strong stance and "call for researchers from different research traditions to develop a common non-hierarchical matrix, for the identification of features of bilingual/multilingual education programmes all over the world, to help researchers carry out comparative studies across contexts" (2014:217). It is evident that a new model is required to bring clarity to this situation and provide a framework for categorizing different implementations of CLIL, but until a valid construct emerges, it is critical that studies into CLIL programmes give precise descriptions of the given circumstances, so researchers can assess whether the results hold in different contexts.

Numerous studies in the field show that CLIL occurs in a variety of different forms; however, certain generalisations on common features can be made. Dalton-Puffer *et al.* describe three prototypical characteristics drawn from findings in empirical research (2014: 214-215):

1. The target languages of CLIL programmes are predominantly lingua francae, in particular English.
2. CLIL classes are taught in addition to and not instead of traditional foreign language classes.
3. CLIL classes are scheduled in content lessons taught by teachers who are trained in the subject content.

These findings indicate that CLIL programmes follow certain trends, and as the body of research in the field continues to grow, researchers will be able to provide greater clarity on the variables affecting the implementation and success of CLIL.

In conclusion, it can be said that CLIL acts as an umbrella term for any dual-focused approach in which an additional language is used for teaching content. Such a definition of CLIL is deliberately general in order to encompass a wide range of approaches, and while it has been criticised by some as ill-defined, this conception allows CLIL to act as a unifying term for teaching models which integrate language and content (see Eurydice 2006). Future work in the field may seek to create a framework for categorizing CLIL programmes according to certain characteristics to counter any claims of ambiguity. Finally, although implementations CLIL can greatly vary, there are also certain typical features, for instance that English is the prominent language in CLIL programmes (Dalton-Puffer *et al.* 2014: 215).

## 2.4. Research into CLIL

The impact of CLIL education on learning of the target language and on the acquisition of content knowledge is not the main focus of this thesis. Nevertheless, the following sections will provide a general overview of research investigating these areas in order to provide a general rationale for the implementation of CLIL in mainstream education.

### 2.4.1. Research on immersion

Due to its close relationship with CLIL, discussed in more detail in section 2.1., research into immersion has particular relevance for the field, although naturally any implications for CLIL should be interpreted tentatively. Furthermore, immersion has a longer history of academic study, and consequently it is backed by a greater body of research.

Drawing on a number of studies and publications, Pérez-Cañado summarises the main findings of research into immersion education (2012: 317):

1. Students in immersion programmes achieve impressively high language levels, consistently outscoring students taught in a traditional foreign language teaching context. Notably, immersion leads to native-like proficiency in receptive skills. The productive skills, however, do not reach quite the same level.
2. Immersion programmes have no negative impact on the acquisition of subject matter, and its students acquire content knowledge to the same degree as in monolingual teaching.
3. There is no negative impact on the development of students' native languages.
4. Cognitive development is also positively affected with students' displaying greater conceptual understanding of the languages.
5. In general, students display positive attitudes towards the immersion language and its native speakers.

Such a characterization of immersion is the result of over three decades of research into the approach, during which time the methodology was repeatedly refined and developed, and although CLIL occurs in different circumstances to the immersion programmes in Canada, it can be expected that some of these findings also apply. Consequently, it can be presumed that well-founded implementations of CLIL have a positive impact on learning the target language and also that there is no negative effect on the acquisition of content knowledge or on the development of the first language.

### 2.4.2. CLIL and the target language

Research into the effect of CLIL instruction on proficiency in the target language has overwhelmingly shown a positive impact. Martínez Agudo (2019: 2) presents a comprehensive overview of studies conducted in this area across Europe and highlights the benefits of CLIL instruction in language proficiency, in particular for receptive skills and vocabulary acquisition.

An early longitudinal study conducted in the 1990s in the Netherlands by Admiraal, Westhoff, and de Bot on the effect of bilingual education in secondary school on language level concluded that partial immersion of students "led to better results in language proficiency in the target language than regular education" (2006: 89-91). The research project worked with a large data sample, analysing a number of tests completed by each of the 1,305 participants from five different schools. In particular, the authors established that students scored higher in tests of receptive vocabulary throughout the duration of the programme (2006: 83-84). These findings were emulated in a study of 130 sixth grade female students by Jimenez Catalan and Ruiz de Zarobe, in which a CLIL group scored better than the non-CLIL control group in three different tests of receptive vocabulary (2009). Although these results suggest promising results for bilingual education, the Admiraal, Westhoff, and de Bot caution against making any general conclusions regarding the effect of CLIL, emphasizing the unique circumstances of their study: "the schools of this study offering bilingual education were all pioneer schools" (2006: 91).

Since the emergence of CLIL in the 1990s, Spain has emerged as a leading region in introducing CLIL in mainstream education. This development has been accompanied by widespread research into the approach. For instance, in their evaluation of bilingual education in Andalusia, which included over one thousand participants, Lorenzo, Casal, and Moore found that, after receiving one and a half years of CLIL teaching, students in the bilingual English programmes scored significantly higher than the control group in all four language competences, reading, listening, reading, and writing (2009). In analysing their results, the authors comment that "Considering that the only feature which distinguishes these two groups is that the bilingual learners have had one and a half years of CLIL, the difference is striking" (Lorenzo, Casal & Moore 2009: 427).

In his analysis of the language competence of CLIL and non-CLIL students in the Basque Country, Lasagabaster comes to a similar conclusion with his results showing that CLIL instruction led to better results in all languages competences tested, namely listening, grammar, speaking, and writing (2008). However, the author also draws attention to a problematic issue found with many studies, namely that "it has to be considered that students who chose the demanding CLIL programmes may have been more academically gifted and more motivated than their non-CLIL counterparts" (Lasagabaster 2008: 39). This point of contention is strongly reiterated by Bruton who strongly criticises numerous studies of CLIL which fail to take into account that "it is generally acknowledged that essentially the students who opt for, and are very often encouraged into, the bilingual programmes are the highly motivated ones, whose parents are generally in the higher socio-economic classes" (2011: 529).

It is important to factor the argument that CLIL strands may be pre-selective into any general analysis comparing the language proficiency of CLIL and non-CLIL students. However, it must be said that there is now an overwhelming amount of evidence from different sources documenting positive impacts of CLIL. For instance, Coral, Lleixà, and Ventura investigated the results of students from 85 primary school in a state-wide language competence test administered to sixth-year students in Catalonia (2018). They found that schools implementing CLIL obtained slightly better results than their non-CLIL counterparts, while the ideal school of reference, which offers a well-researched PE-in-CLIL programme, strongly outperformed all other schools. In another recent study conducted in Extremadura, Martínez Agudo administered tests of receptive skills, vocabulary knowledge, and use of English to students from both CLIL and non-CLIL streams in public schools as well as from charter (private) schools which did not offer any CLIL instruction (2019: 4-5). According to the author, analysis of the data "confirm[s] that in public schools, the CLIL groups tended to achieve better results than the non-CLIL groups on all measures of language competence" (Martínez Agudo 2019: 10). Furthermore, his results show that CLIL groups in public school acquire a similar level of language proficiency to non-CLIL students of charter schools, suggesting that CLIL can be viewed as a possible approach to achieve greater social equality in education. Such findings counter Bruton's (2011) claim that higher language achievement in CLIL strands can be ascribed completely to pre-selection.

A wide range of studies have found CLIL instruction to have a positive impact on language development, but numerous authors have been cautious in making general statements on its advantages. Lorenzo, Casal, and Moore, for instance state that "it is still too early to infer any generalised outcomes for European CLIL" (2009: 436). Martínez Agudo also notes that the "The findings from this study do need to be interpreted with some caution as, despite our best efforts to achieve homogeneity of the CLIL and non-CLIL groups, it was not possible to control for the effects of all possible factors" (2018: 9). One underlying cause for an overall hesitancy to make assertions is the fact that, as described in detail in section 2.3., CLIL occurs in such a variety of different contexts that transferring results remains problematic. In addition, it must be said that it is impossible for researchers to control for all variables affecting language development in CLIL classrooms, and this may also lead to a measure of doubt in proclaiming general success.

Bruton (2011), in particular, has discussed this variability of studies into CLIL and taken a very critical view of the research. In his article, he analyses the methodology of various studies which find CLIL to be beneficial for foreign language learning and highlights numerous problematic issues with the interpretation of the data used for the research. Bruton's view of CLIL as presented in these studies is that "nothing conclusive can be shown with no pre-post average scores, no valid comparison groups, and no comparable contexts, with no control over extra FL instruction outside school, and the support of additional teachers and coordination time" (2011: 530). In a more recent publication, the author even describes much of the research into CLIL as "theoretical and empirical donkey work" (2017: 11). Bruton's (2015: 122) extreme view seems formed on the idea that the results of the qualitative analyses conducted in studies of CLIL are misrepresented and should be interpreted differently. While a certain degree of objectivity is inevitable in qualitative studies, education is such a complex field that it is impossible to reduce completely to numbers, and the overwhelming evidence presented in the array of available publications provides a strong scientific backing for CLIL. His overall critique is justifiable in the sense that it reveals certain aspects which should be considered in the methodology of future studies, but an overall negative view of CLIL is unfounded.

Criticism of the methodology used in studies ascribing a positive impact to CLIL with regards to language development coupled with a general hesitancy to generalize successful implementations of CLIL may act as a counterincentive to widespread adoption of the method. While it is important to acknowledge shortcomings in empirical studies and also maintain a cautious attitude in transferring results, there a general consensus among most academics that CLIL instruction is beneficial for the development of proficiency in the target language. Although individual studies may have methodological flaws, research has overwhelmingly shown CLIL to have a positive impact in all four language competences: listening (see Dallinger *et al.* 2016), reading (see Prieto-Arranz *et al.* 2015), speaking (see Ruiz de Zarobe 2008), and writing (see Jexenflicker & Dalton-Puffer 2010; Ruiz de

Zarobe 2010). Consequently, there can be no doubt that CLIL can certainly be viewed as a valid approach to improve student learning of foreign languages.

### 2.4.3. CLIL and content learning

Learning content is a foreign language is a challenge for many students, and consequently it is possible to presume that in CLIL programmes the benefits in language learning may come at the cost of subject knowledge. Bruton comments on this issue stating that in CLIL "a student's weakness in a content subject could be compounded by a weakness in the FL" (Bruton 2017: 7). In this context, it is crucial to guarantee that students in CLIL classes achieve the same level of content knowledge in as in identical classes taught in students' first language.

In this discussion, it is firstly important to note that the CLIL approach by its very definition emphasizes the importance content learning and attributes it the same importance as language learning. Subsequently, it can be presumed that teaching in the foreign language should not be detrimental to the acquisition of subject knowledge. Furthermore, as mentioned in section 2.4.1., findings from immersion education show that students "perform satisfactorily in the subject matter taught in the second language, assimilating this knowledge at the same high level as the monolingual control groups" (Perez-Canado 2012: 317). These two points provide an underlying foundation for the assumption that students in CLIL programmes will acquire content knowledge at a similar rate as students taught in their first language.

The above inference is underlined by findings from empirical research. Perez-Canado conducted a study on the effect of CLIL instruction on both the L1 and content knowledge with a sample of 2024 students and concludes that "Public and private bilingual school students thus perform better than or just as well as public and charter non-bilingual pupils on subject content, so that it can be claimed that CLIL is not watering down content learning in either Primary or Secondary Education" (2018: 24). These results were replicated in a study of secondary physics students in Italy by Rosi, albeit with a smaller sample of 54 students, suggesting that CLIL instruction may even have a positive impact on the acquisition of content-specific knowledge (2018). However, other publications have also reached different conclusions. For instance, in a study involving 709 primary students in Spain, Fernández-Sanjurjo, Fernández-Costales and Arias Blanco found that non-CLIL students outperformed the CLIL students in content knowledge in science (2019). That being said, the authors also comment that their results, which contradict much prior research, may be affected by various contextual factors, for example that "many parents do not have sufficient language competence in English to help their children" (Fernández-Sanjurjo, Fernández-Costales & Arias Blanco 2019: 669). A further study by Piesche *et al.* (2016) tested a group of 722 students who were randomly assigned to a group receiving physics instruction for five 90-minute lessons in either German, the students' native language, or English. The results show that the group instructed in German significantly outperformed their English counterparts both in a short-term and long-term test of content knowledge. The authors conclude that the "study sensitizes for possibly negative effects of CLIL on content learning for students without CLIL experience and supports the need for future research on effective CLIL-teaching methods" (Piesche et al. 2016: 115).

In conclusion, the research shows that, in general, if teaching is well-organised and the students adequately prepared, CLIL instruction does not negatively impact the acquisition of content-specific knowledge. In certain cases, it has even been found to benefit students' understanding of subject matter. It is, however, important to note that context strongly affects the success of CLIL, in particular with regard to content learning, and consequently the unique linguistic circumstances of every region need to be considered in organizing any CLIL programme.

#### 2.4.4. The integration of language and content in CLIL

The previous sections have established a clear rationale for extensive adoption of the CLIL approach. Research has shown that there are significant benefits in language learning and also that the acquisition of content-specific knowledge is not negatively affected. Studies investigating these two strands of language learning and content learning in isolation have proved important in providing an empirically backed justification for CLIL, but they fail to recognize the core characteristic of CLIL, namely the integration of content and language.

To date, the integration of content and language in CLIL classes has not been the main focus of research in the field. In the publication *Conceptualising Integration in CLIL and Multilingual Education*, Nikula *et al.* recognize this development in the following passage (2016: 1):

> Even though the [...] duality of content and language lies at the heart of CLIL and has been acknowledged in most studies, CLIL research to date has been mainly characterised by language learning perspectives on learners' general language skills. That is, there has been less research on how content and language integration challenges our views of language and on the importance of language in and for content learning

The authors indicate a research gap in the conceptual space in which language and content overlap. Llinares also notes that this area is of interest to academics from different strands of bilingual education, writing that the "actual concept of integration, what it entails and how it can be materialised in the classroom, should receive more attention by researchers and practitioners, no matter whether the context at hand is a so-called immersion setting in Canada or a so-called CLIL school in the Netherlands" (2015: 59).

It is evident that this area requires greater attention, and researchers have developed some theoretical constructs to investigate the overlap of content and language in CLIL classrooms. An early and well-known model is the 4Cs framework, first presented by Coyle in her 1999 book chapter "Theory and planning for effective classrooms: Supporting students in content and language integrated learning contexts". The model aims to act as a link between the pedagogies of language teaching and subject teaching – two areas, which are generally considered separate in traditional views of education (Coyle 2007: 549). According to Coyle, this is achieved by focusing on the connections in the four areas of content, communication, cognition, and culture, as illustrated in the figure below (Coyle 2006 in Coyle 2007: 551):

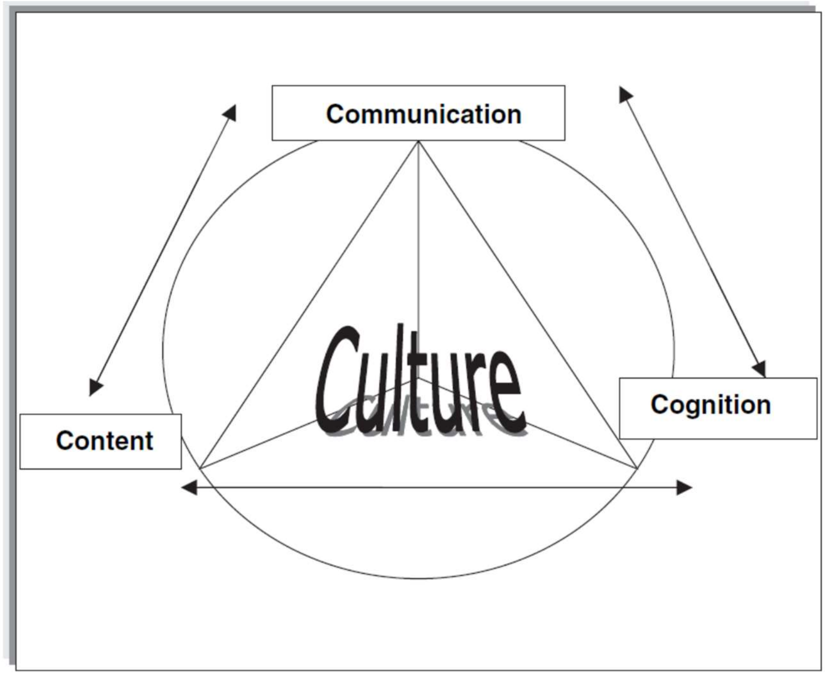



**Figure 1 The 4Cs Framework (Coyle 2006 in Coyle 2007: 551)**

Figure 1 clearly shows that culture is the aspect at the centre of the framework and as such functions as a linker between all the areas. The 4Cs framework is effective in the sense that it provides a theoretical model to link previously separate pedagogies, and it can act a useful tool in helping teachers to prepare CLIL lessons. However, the construct's limitations are evident when considering it from the CLIL researcher's perspective, as there is no practical application into how to conduct empirical analyses of the integration of language and content in actual CLIL teaching. From this perspective, alternative approaches are necessary to investigate CLIL effectively.

In the development of CLIL research since the 4Cs framework, two main strands have emerged in methodical approaches investigating the integration of content and language in CLIL teaching, namely classroom discourse and systemic-functional linguistics (Llinares 2015: 61). Systemic-functional linguistics examines student's use of language in relation to three overarching metafunctions: ideational, interpersonal, and textual (Llinares 2015: 62). However, as classroom discourse analysis has been chosen as the methodological approach for this thesis' study, the latter will form the main focus of this text.

### 2.4.5. Classroom discourse in CLIL

Classroom discourse analysis has become recognized as a valid approach to research the integration of content and language in CLIL classes (see Dalton-Puffer 2007; Nikula, Dalton-Puffer & Llinares 2013; Llinares 2015). Nikula, Dalton-Puffer and Llinares maintain that, while classroom discourse analysis can also be conducted to investigate language use and language learning, the construct specifically provides insight into the construction of knowledge, as illustrated in Figure 2 (2013: 74):

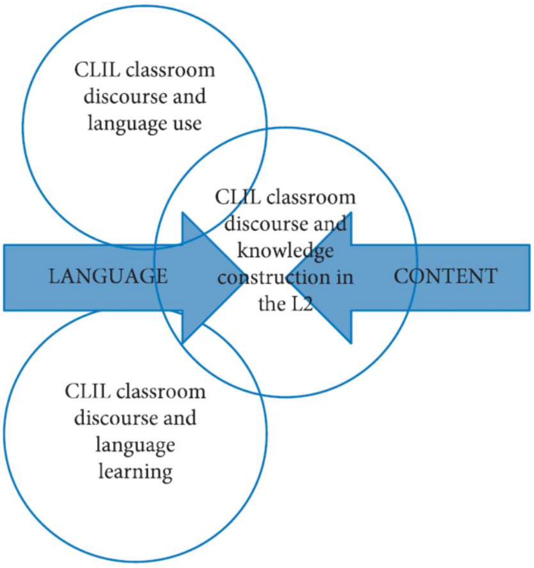



**Figure 2 Focus areas in CLIL Classroom Discourse Research (Nikula, Dalton-Puffer & Llinares 2013: 74)**

In particular, Figure 2 highlights that classroom discourse analysis allows researchers to study the conceptual space in which content and language learning overlap, an area which has been identified as a critical research focus for future studies of CLIL.

A seminal publication in the field of classroom discourse research into CLIL, and also of particular relevance to this thesis, is Dalton-Puffer's work *Discourse in Content and Language Integrated Learning (CLIL) Classrooms* (2007). The book presents a qualitative study of CLIL classroom discourse in Austria, drawing on data from recordings of 40 lessons, involving a total of 305 students and taking place in one of seven different schools. Dalton-Puffer uses a variety of analytical frameworks to analyse classroom discourse: genre analysis, speech acts, Conversation analysis, oral practices, and discourse grammar (2007: 44). This multi-facetted analysis provides a detailed insight into various aspects of CLIL classroom discourse, and the author notes that the main focus of future research should be to "to refine the conceptual and to broaden the empirical basis of 'English for knowledge acquisition' within CLIL" (2007: 297).

Two main points from Dalton-Puffer's publication should be emphasized in the context of this thesis. Firstly, the author points out that further research should focus on collecting empirical evidence to develop greater understanding for the role of language in the construction of knowledge in CLIL (2007: 297). Secondly, it is critical to note that Dalton-Puffer's extensive and intensive research locates her as an expert in the field of CLIL classroom discourse, and her continued work in this area has led to the development of the cognitive discourse functions construct, which is used as the framework for analyses in this thesis.

# 3. CLIL & mathematics: the nature of the subject

Overall, it can be said that mathematics takes on a somewhat unique role in education. It is universally perceived as an essential area of knowledge, deeply engrained in school curricula all over the world, but the subject is also widely abhorred by students with many leaving school with a negative attitude towards mathematics. These specific features of mathematics cannot be ignored when exploring classroom discourse in CLIL mathematics classroom. As such, this chapter seeks to characterize mathematics in an educational context and also introduce previous research investigating CLIL in mathematics in order to provide an outlook for the area of inquiry of this thesis.

Mathematics, in contrast, for instance, to languages, is regarded as a hard science, which means the subject is characterised by a high degree of certainty. Ernest emphasizes this feature writing that "mathematics has long been taken as the source of the most certain knowledge known to humankind" (1991: 4). He further elaborates on the nature of mathematics in the following passage (1991: 4):

> Mathematical knowledge [...] consists of propositions asserted on the basis of reason alone. Reason includes deductive logic and definitions which are used, in conjunction with an assumed set of mathematical axioms or postulates, as a basis from which to infer mathematical knowledge. Thus the foundation of mathematical knowledge, that is the grounds for asserting the truth of mathematical propositions, consists of deductive proof

This aspect of mathematics has some major implications for mathematics teaching. Firstly, as knowledge is constructed purely through deductive reasoning, subjective opinions are, in general, perceived as unwarranted in mathematics classes. Secondly, the conceptual clarity of the subject means answers can as a rule be classed as either right or wrong – there is no middle ground. These two aspects of mathematics are particularly relevant as they are likely to have a major impact on language used in CLIL mathematics classes.

A further important characteristic of mathematics is the use of an exclusive collection of terms, symbols and graphical representations, which students are usually not familiar with from outside of school. This has led to a common perception of mathematics as its own kind of language, a view which is echoed by Kenney in the following statement: "[m]athematics truly is a foreign language for most students: it is learned almost entirely at school and is not spoken at home" (2005: 5). He elaborates on this statement, presenting a collection of confusing terms, formats and symbols in mathematics of which an extract is presented below in Figure 3 (2005: 7):


CONFUSING FORMATS
analog and digital clocks
angle rotation
quadrant layout
superscripts and subscripts
various types of graphs

CONFUSING SYMBOLS
$\surd$ and $\overline{)\ }$
•, ×, (  ), and *
÷, $\overline{)\ }$, /, and $\frac{m}{n}$
=, ≡, ~, ≈, and ≅
< and >

**Figure 3 Confusing formats and symbols in mathematics (Kenney 2005: 7)**

Figure 3 gives only a small insight into some of the many different methods of representation used in mathematics. Dale and Cuevas (1987: 12) also point out that not only does mathematics include vocabulary items completely new to students but also that familiar words take on different meanings in the mathematical context, giving the examples "*equal*, *rational*, *irrational*, *column*, and *table*". For students, these complex language dimensions often increase the challenge of mathematics, as not only are they required to understand a variety of complex concepts, but also learn the special language and symbols used to communicate mathematics.

At first, the additional challenge of learning mathematics, which can be viewed as a separate language in itself, in a foreign language, as is the case for CLIL mathematics classes, may seem like an unreasonable burden for students. However, a closer consideration of these unique circumstances indicates that there may indeed be advantages to implementing CLIL in mathematics. As illustrated in Figure 4 the linguistic space of the CLIL mathematics classroom takes on a triangular nature. This means that, in contrast to a conventional language teaching or CLIL context, there is not a singular, one-to-one relationship between the L1 and the L2, as shown in Figure 5, but rather a triangular form in which each language is linked with two other languages:

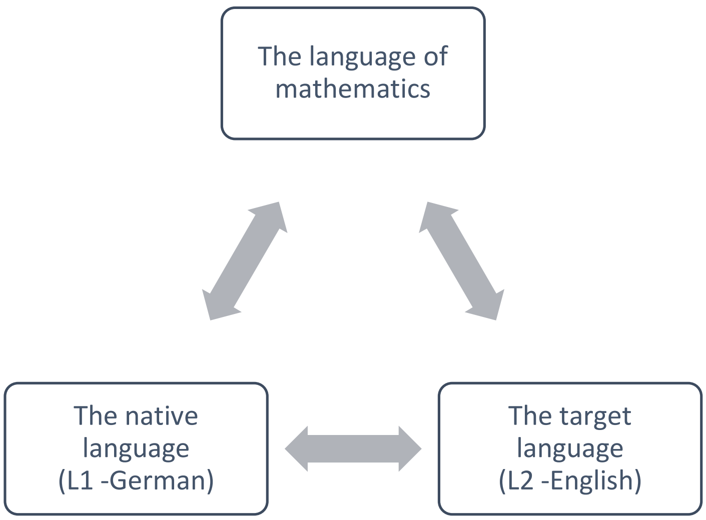



**Figure 4 The triangular linguistic space of the CLIL mathematics classroom**

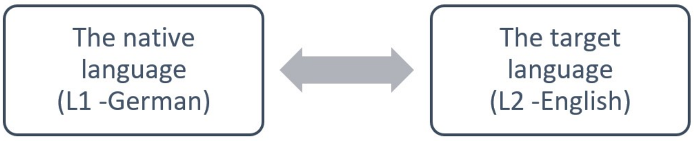



**Figure 5 The linguistic relationships of a conventional language teaching or CLIL classroom**

A consequence of this is that students develop greater networks of meaning for mathematical concepts as well as for the target language. As an example, a student may be familiar with both the German term and mathematical representation for a certain concept. When learning the appropriate English terminology, the vocabulary is linked not only to the German translation but also to mathematical representation. This is further illustrated in Figure 6 below, applied to the example of the set of integers:

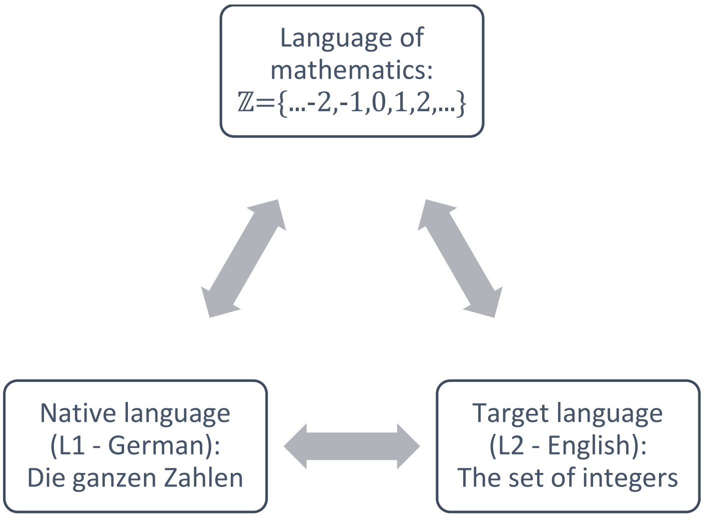



**Figure 6 Example of trilingual nature of CLIL mathematics classrooms**

The above characterisation is an untested model, but if we assume such a viewpoint, then the CLIL mathematics classroom can be said to hold enormous potential with regard to student learning, although much research is required to provide any empirical validation of this presumption.

While mathematics may seem a well-suited subject for implementing CLIL, specific publications on research into the discourse of such classrooms is limited. One publication of note is Wilhelmer's (2008) book *Content and Language Integrated Learning (CLIL): Teaching Mathematics in English*. The author presents an overview of methodologies and didactics of CLIL in mathematics, but the most interesting component of her work is the qualitative study in which she interviewed five teachers from three different school in Austria who had each been teaching mathematics in English for over 10 years (2008: 75-83). A lack of further research in this area as means that the results of Wilhelmer's research must be interpreted with caution. However, there are still some valuable conclusions drawn from the study, which she summarizes in the following list (2008: 106):

1. Teachers should not be scared off by linguistic demands, because mathematical terms can be acquired rather quickly.
2. Teachers report that CLIL does not result in additional difficulties as far as students' comprehension of mathematics is concerned.
3. Students mathematical competence does not seem to suffer.
4. Competence in the L2 is no appraisal factor.
5. There is no need to exclusively stick to the L2 as the use of the L1 often acts as a support and facilitates students' understanding.
6. Mathematics does indeed seem to be a good starting point for the use of CLIL.

Her findings indicate that the teachers had very positive experiences and impressions of teaching mathematics in English. Firstly, it should be noted that the second point is in alignment with findings of other studies discussed in section 2.4.3. that content knowledge is not negatively impacted by teaching a different language. Furthermore, the first and fifth conclusion of the list support the model introduced previously, namely that the three languages used in mathematics aid students in negotiating meaning.

This chapter has aimed to give a brief overview of the nature of mathematics and the relationship of language and content in mathematics teaching, so as to provide an outlook for the focus of this thesis. Firstly, it can be noted that conceptualizing the CLIL mathematics classroom as a trilingual linguistic space holds great opportunities for negotiating meaning, although such a model must be closely scrutinized. Furthermore, while empirical research into dual-lingual approaches to mathematics teaching are limited, preliminary findings are promising, in particular the information gathered in Wilhelmer's (2008) study of CLIL in mathematics classes in Austria. In conclusion, it can be said that as a subject, mathematics holds great potential for testing and refining CLIL practice, and the construct presented in the next section will bring a new perspective to the current body of research into the discourse of CLIL mathematics classroom.

# 4. Dalton-Puffer's construct of cognitive discourse functions (CDFs)

The following chapter introduces Dalton-Puffer's construct of cognitive discourse functions, first presented in the 2013 article "A construct of cognitive discourse functions for conceptualising content-language integration in CLIL and multilingual education", in three main steps. Firstly, the rationale for developing the construct will be discussed. The second part of this chapter will present the theoretical background of CDFs with the purpose of providing an empirical justification for its use. Finally, the construct itself will be introduced giving detailed descriptions of the seven different types of CDFs by both referring to previous applications of the construct and relating each CDF type to the mathematical context, in order to set a framework for the qualitative study.

## 4.1. Rationale for the CDF construct

As outlined in greater detail ins section 2.4. much of the previous research into CLIL has investigated the development of language skills or the acquisition of content knowledge, and numerous experts have pointed out that there needs to be a greater focus on the actual integration of these two areas. This trend has highlighted the lack of an appropriate, widely-accepted tool for connecting language and content, an issue identified by Dalton-Puffer: "What is at issue, then, is the need to link up the pedagogies of the different subjects like mathematics, history or economics with the pedagogy of language teaching" (2013: 219). Classroom discourse analysis has emerged as a possible approach for researching integration in multilingual settings, and Dalton-Puffer (2007) has, prior to the development of the CDF construct, used a variety of different frameworks, mentioned in section 2.4.5., to analyse CLIL. However, while the 2007 study of CLIL class in Austria provides great insight into various aspects of classroom discourse, it offers no practical model available to educators and researchers to conceptualise integration.

The CDF construct then seeks to bridge this gap and aims to provide a framework allowing for a convergence of the language and content perspectives in both teaching and research. Dalton-Puffer states this explicitly in her article introducing the CDFs (2013: 242):

> My main argument in this article, then, has been that in order to enable (rather than claim) content-and-language integration in classroom teaching, it is imperative to identify an area of sufficient overlap between the recontextualisations of subject education and language education for them to be able to march together. My claim is that cognitive discourse functions constitute such an area of overlap.

Furthermore, Dalton-Puffer states that "the CDFs can function as a kind of lingua franca that may enable educators to communicate across subject boundaries" (Dalton-Puffer 2013: 242). This again emphasizes that the construct acts as a common means of communication for experts from different fields to form a shared understanding of the cognitive thinking processes in CLIL. The rationale for the development of the CDF construct means it is well-suited as a methodology for the research focus of this thesis, namely to investigate the integration of language and content in CLIL mathematics classes.

## 4.2. Theoretical background of the CDFs

The core idea of the CDF construct is to analyse the integration of language and content in dual-focused teaching approaches specifically by “by making visible how disciplinary thought processes are handled in classroom talk.” (Dalton-Puffer 2013: 232). While the CDF construct is the first of its kind in specifically focusing on thinking acts in a multilingual context, much prior research has focused on describing the cognitive processes taking place in learning, and Dalton-Puffer (2013)draws on a number of different models in establishing a theoretical foundation for the CDFs.

Dalton-Puffer firstly refers to Bloom’s *Taxonomy of educational objectives* (1956) as a pioneering document in the field and then presents Anderson, Krathwohl et al.’s (2001) more recent revision as an important predecessor of the CDFs (2013: 221). In particular, Anderson, Krathwohl et al. create a two-dimensional model allocating cognitive objectives according to the two variables of knowledge dimensions and cognitive processes, as shown below in Figure 7 (2001: 28):

| ***Knowledge Dimensions*** | **Cognitive Processes** | | | | | |
|---|---|---|---|---|---|---|
| | Remembering | Understanding | Applying | Analyzing | Evaluating | Creating |
| *Factual* | | | | | | |
| *Conceptual* | | | | | | |
| *Procedural* | | | | | | |
| *Metacognitive* | | | | | | |

**Figure 7 Revised taxonomy of cognitive objectives (Anderson, Krathwohl & al 2001: 28)**

The table presented in Figure 7 highlights what Dalton-Puffer refers to an “understanding of ‘thinking skill’ as a matrix rather than a hierarchy” (2013: 222). Furthermore, Anderson, Krathwohl et al. allocate a number of concrete cognitive processes to each of the six categories shown in Figure 7, and an overview of this conceptualisation is given in Figure 8 on the next page (2001: 31):

| | |
|---|---|
| REMEMBER | RECOGNISING, RECALLING |
| UNDERSTAND | INTERPRETING, EXEMPLIFYING, CLASSIFYING, SUMMARISING, INFERRING, COMPARING, EXPLAINING |
| APPLY | EXECUTING, IMPLEMENTING |
| ANALYSE | DIFFERENTIATING, ORGANISING, ATTRIBUTING |
| EVALUATE | CHECKING, CRITIQUING |
| CREATE | GENERATING, PLANNING, PRODUCING |

**Figure 8 the six categories of cognitive processes and corresponding cognitive processes (Anderson, Krathwohl & al. 2001: 31)**

The relevance of Anderson, Krathwohl *et al.*'s (2001) taxonomy for the CDF construct is twofold. Firstly, Dalton-Puffer uses a similar structural approach for the CDFs, creating seven overarching functions with a number of members in each category, which mirrors the approach adopted by Anderson, Krathwohl *et al.* (2001) shown in Figure 8. Secondly, Dalton-Puffer notes that Anderson, Krathwohl *et al.*'s (2001) work provided a foundation for the creation of her own construct, in particular highlighting the three dimensions understanding, analysing, and evaluating (2013: 222).

A further important influence in the construction of the CDFs is the hierarchy of verbs presented by Biggs and Tang used to describe learning processes (2011). Dalton-Puffer presents a simplified version of the hierarchy shown below in Figure 9 (based on Biggs and Tang 2011; simplified in Dalton-Puffer 2013: 222):

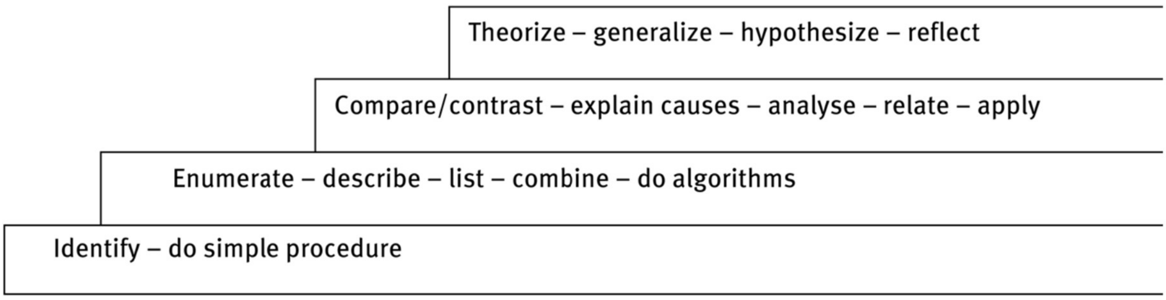



**Figure 9 Verbs for formulating learning outcomes (Dalton-Puffer 2013: 222)**

The clear overview of verbs shown in Figure 9 allows for a direct comparison with Anderson, Krathwohl et al.'s (2001) taxonomy shown in Figure 8, and as can be expected, there are some similarities, for instance the thinking processes analysing and comparing, which occur in both models.

Anderson, Krathwohl *et al*.'s (2001) taxonomy and Biggs and Tang's (2011) hierarchy provide useful frameworks for conceptualising thinking skills and formulating learning outcomes. However, the models do not describe the specific linguistic skills required to demonstrate the various cognitive processes. In this regard, Dalton-Puffer alludes to the work of Bailey with several collaborators, which aims to describe the academic language requirements of high school students in the USA (for full overview see Dalton-Puffer 2013: 223). Of particular relevance for the CDF construct is a publication by Bailey and Butler, which specifies verbs describing the functions necessary in language use across the curriculum, for instance "*analyze, contrast, define, elaborate, hypothesize,* and *justify*" (2003: 17). In this context, Bailey and Butler's (2003) document can be seen as an important predecessor of the CDF construct, as in their work, they strive to describe the language functions required in teaching non-language subjects.

An additional influential project in the creation of the CDF construct is the *Language in other Subjects* platform administered by the Council of Europe (https://www.coe.int/en/web/platform-plurilingual-intercultural-language-education/language-s-in-other-subjects). The platform offers a variety of reference texts describing the language requirements in different subjects. Dalton-Puffer refers explicitly to Vollmer's (2010) work, which focuses on language use in science classrooms. However, as the research focus of this thesis is CLIL in mathematics classes, the document written by Linneweber-Lammerskitten (2012) describing the linguistic competences necessary for teaching and learning mathematics is of particular relevance.

Linneweber-Lammerskitten's publication on language use in mathematicas refers explicitly to "*discourse functions* [...] [which] are to be understood as the discursive representation of both the cognitive processes and their linguistic realisation (in the sense of enactment) brought into play for the development/exposition of knowledge" (2012: 26). Furthermore, the author differentiates between 'macro functions', which act as overarching categories, and 'micro functions', which describe both cognitive processes and their verbal enactments and may be attributed to more than one macro function. Table 1 and Table 2 list the different functions as taken from Linneweber-Lammerskitten (2012: 27):

| |
|---|
| 1. Exploring/processing/documenting |
| 2. Naming/defining |
| 3. Describing |
| 4. Reporting |
| 5. Explaining |
| 6. Evaluating |
| 7. Arguing |
| 8. Exchanging/negotiating |
| 9. Narrating |
| 10. Creating |
| 11. Reflecting (e.g. about learning paths + results |
| 12. Acting (symbolically or by way of simulation |

**Table 1 A collection of macro functions (Linneweber-Lammerskitten 2012: 27)**

| | | | |
|---|---|---|---|
| Asking questions | Labelling | Presenting | Hypothesizing |
| Questioning | Collecting | Sequencing | Predicting |
| Guessing | Selecting | Relating | ... |
| Identifying | Reporting | Structuring | |
| Classifying | Summarizing | Contrasting | |

**Table 2 A list of micro functions (Linneweber-Lammerskitten 2012: 27)**

While Table 1 and Table 2 both show numerous examples of macro and micro functions, Linneweber-Lammerskitten (2012: 27) maintains that these lists are not exhaustive and that other functions may be added. Furthermore, the author also provides concrete examples of realisations of certain micro functions in mathematics classes including the following examples (2010: 28):

- *Reporting / recounting* (on a solution of a problem/exploration)
- *Classifying* (mathematical objects, properties, relations, procedures)
- *Defining / determining* (a mathematical term, a mathematical state of affairs)

Although Linneweber-Lammerskitten's (2012) work does not consider a multilingual setting, his research provides great insight into the language requirements of mathematics classrooms, and consequently, his publication with be consulted to provide a mathematical perspective on the different types of CDFs.

In addition to the subject-education perspective, Dalton-Puffer (2013) also approaches the area of inquiry from the viewpoint of applied linguistics focussing on the use of academic language. In this context, an author of particular significance is Cummins (2000), who in his work differentiates between basic interpersonal communicative skills (BICS) and cognitive academic language proficiency (CALP). This distinction highlights the difference between a language learner's ability to communicate in an informal, conversational manner (BICS) in contrast to successfully using a language. in a specific academic context (CALP). In particular, Cummins notes that the construct aims to draw attention to the different functions of language, and he emphasizes that the "different aspects of proficiency cannot be considered to reflect just one unitary proficiency dimension" (2000: 59). Cummin's binary model indicates the multi-faceted nature of language proficiency, and Dalton-Puffer maintains that the CDF construct provides a tool for researching the "different oral and literate uses of language [in classroom interaction]" (2013: 227).

The above descriptions indicate that the CDF construct is backed by a wide range of prior research, both by publications on general education objectives as well as applied linguistics approaches to classroom interaction. Furthermore, Dalton-Puffer's overview of theoretical frameworks informing the creation of the CDFs illustrates that the construct has "conceptual roots in both curriculum and applied linguistics"

(2013: 227). Consequently, it can be viewed as an appropriate tool for studying the integration of language and content in CLIL classroom.

## 4.3. The CDF construct

### 4.3.1. Introducing CDFs

As previously described in section 4.1., the CDF construct was "developed in order to support research and development on the integration of content and language pedagogies in all forms of multilingual education by making visible how disciplinary thought processes are handled in classroom talk" (Dalton-Puffer 2013: 232). The validity of the construct is backed both by research undertaken from the general educational and the applied linguistics perspective as well as Dalton-Puffer's prior work in the area of classroom discourse which highlights some of the features previously used to study the integration of content and language (2007: 295):

> Academic language skills and functions in the oral and written modality must be identified and implemented systematically (describing, defining, explaining, informing, arguing, hypothesizing; plus a progression of narrative, descriptive, informative, argumentative, and persuasive texts) in conjunction with subject specific and general academic vocabulary development.

This passage, published numerous years before the CDF construct was introduced, also provides some insight into the Dalton-Puffer's previous work informing the framework, and some of the functions mentioned above (describing, defining) are adopted directly.

Initially, Dalton-Puffer's literature review provided a collection of around 50 different functions (for full list see Dalton-Puffer 2013: 251-253). These were then grouped according to seven overarching types, each describing a different "communicative intention which forms the core of the function" (Dalton-Puffer 2013: 234). Table 3 below provides an overview of the seven different functions (Dalton-Puffer 2013: 234):

| *Function Type* | Communicative Intention | Label |
|---|---|---|
| *Type 1* | I tell you how we can cut up the world according to certain ideas | CLASSIFY |
| *Type 2* | I tell you about the extension of this object of specialist knowledge | DEFINE |
| *Type 3* | I tell you details of what can be seen (also metaphorically) | DESCRIBE |
| *Type 4* | I tell you what my position is vis a vis X | EVALUATE |
| *Type 5* | I give you reasons for and tell you cause/s of X | EXPLAIN |
| *Type 6* | I tell you something that is potential | EXPLORE |
| *Type 7* | I tell you about sth. external to our immediate context on which I have a legitimate knowledge claim | REPORT |

**Table 3 List of CDF types and underlying communicative intentions**

As can be seen in Table 3, each of the seven types of CDF is attributed a label, shown in column three. However, Dalton-Puffer also points out that these labels cannot be viewed as concrete definitions of the functions and that it should be considered that the meaning of each term is unstable and has fuzzy, unclear boundaries (2013: 235).

The seven categories of CDF each include a number of further labels for different uses of language. An overview is assembled below in Table 4 (Dalton-Puffer 2013: 235):

| | |
|---|---|
| CLASSIFY | Classify, compare, contrast, match, structure, categorize, subsume |
| DEFINE | Define, identify, characterize |
| DESCRIBE | Describe, label, identify, name, specify |
| EVALUATE | Evaluate, judge, argue, justify, take a stance, critique, recommend, comment, reflect, appreciate |
| EXPLAIN | Explain, reason, express cause/effect, draw conclusions, deduce |
| EXPLORE | Explore, hypothesize, speculate, predict, guess, estimate, simulate, take other perspectives |
| REPORT | Report, inform, recount, narrate, present, summarize, relate |

**Table 4 A list of CDF categories and their members**

Reviewing the list, Dalton-Puffer draws attention to the fact that "the categories are not all equally populated, neither are they all equally extensive" (2013: 235). She specifically draws a comparison between the two types *DEFINE* and *EVALUATE*, noting that the former is significantly smaller than the latter. Additionally, Dalton-Puffer also points out that that in some cases, categories may be overlapping, so that a specific function may belong to more than one overarching category (2013: 236). Finally, it is important to note that the construct was specifically designed to be applied in a wide range of different circumstances, and Dalton-Puffer emphasizes that it may need to be adapted when used in any specific context (2013: 237). Application of the CDF construct in various research projects thus far is discussed in greater detail in section 4.4. and adaptations resulting from these findings are presented in section 5.4.1.

### 4.3.2. The seven types of CDFs

In order to provide a concrete framework for analysis of the use cognitive discourse functions in the recordings collected, this section will discuss in detail the properties of the seven different CDFs. This will involve introducing previous findings of the individual functions as well as presenting examples from the data gathered in this study. Two relevant publications, which should be mentioned in this context, are the theses by Kröss (2014) and Hopf and Hofmann (2015), which both analysed the use of CDFs in science classes and were also both supervised by Dalton-Puffer. The two texts are of particular importance as the research was among the first studies to apply the CDF construct to data gathered from naturalistic CLIL classes. In consequence, their work may be viewed as an important predecessor of this thesis, although it should be noted that in this study the area of focus is CLIL implemented in mathematics classes, rather than in science classes.

*CLASSIFY*

The first function introduced by Dalton-Puffer is *CLASSIFY*, which she describes as "a key CDF" (2016: 34). Its importance is emphasized by the fact that Linneweber-Lammerskitten (2012: 27) also lists classify as an important discourse function in mathematics literacy, although in contrast to Dalton-Puffer, he groups it to the micro level.

The previous section mentions the problematic nature of viewing the CDF label as precise definition; however, as previously presented in the analysis by Kröss (2014), the online Oxford English dictionary (OED) entry serves as a useful starting point in analysing the function *CLASSIFY*:

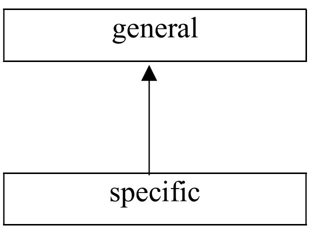
*to classify*

1. to arrange in or analyse into classes according to shared qualities
2. to place in a particular class, esp. to assign a position within a formal system of classification

If classifying is understood as the skill as described in the definition above, an underlying consequence is that in order to be able to correctly classify an object, a person must already have acquired an adequate understanding of the different classes which form a system. Dalton-Puffer also highlights this factor writing that "[t]his [classifying] is a more abstract knowledge type than mere knowledge of terms or facts and it is more complex because classifications actually form links or disjunctures between specific terms and facts" (2016: 34). In this context, *CLASSIFY* can be understood as the ability to categorize objects into a prevailing structure of knowledge.

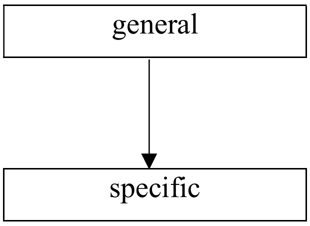
An important categorization of two different types of *CLASSIFY*, presented by both Kröss (2014) and Hopf and Hofmann (2015), is described by Trimble (1985: 85) and Widdowson et al. (1979: 72-75), who differentiate between classification from general to specific and classification from specific to general. The two different realisations are shown in Figure 10 below taken from Widdowson (1979: 75):

**TYPE 1**




| | | |
|---|---|---|
| y | *is a member of*<br>*is placed in the class* | x |

**TYPE 2**




| | | |
|---|---|---|
| y | *Comprises* | y and z |

**Figure 10 The two types of classification according to direction (Widdowson 1979: 75)**

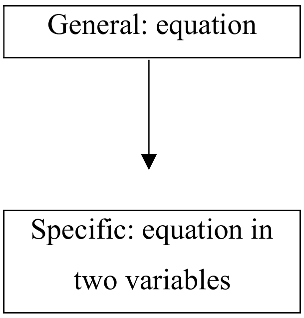
Widdowson et al. (1979) and Trimble (1985) describe CLASSIFY either in a general context or with regard to science subjects, so for the study of this thesis, it is important to establish that these two types of classify are also relevant to CLIL in mathematics. Example 1 shows a passage taken from the recordings exemplifying one of the directions of *CLASSIFY*, namely from general to specific:

Example 1: *CLASSIFY* – general to specific

> T: What is that? That's an equation (.) **What kind of equation** is it? Gentlemen?
> Sm1: A function?
> T: No, it's not a function.
> Sm2: Function equation.
> T: It's a=
> Sm3: =it's a equation in two variables.
> T: It's an equation in two variables (.) That's correct.

In Example 1, the teacher refers to a given example of an equation and asks the students to further specify the type of equation. This leads the students to classify it as an equation in two variables. This example of *CLASSIFY* can be arranged following Widdowson's (1979: 75) framework as shown in Figure 11 below:

**TYPE 2**




| | | |
|---|---|---|
| Equations | *Comprise* | Equations in two variables |

**Figure 11 Example of *CLASSIFY* from general to specific adapted to Widdowson (1979: 75)**

Figure 11 emphasizes that the concrete direction of the classification, namely in the given example from general to specific.

As mentioned in the previous section, there are potential overlaps between the different CDFs, and Dalton-Puffer (2013: 236) writes that "[c]lassifying is always part of DEFINE, but not all instances of

CLASSIFY are”. This means that *CLASSIFY* has a strong interconnection with the next type of CDF, as it can be expected that every realization of *DEFINE* will include an instance of *CLASSIFY*.

*DEFINE*

Defining concepts is as an essential component of any teaching and learning process, and this is reflected by Dalton-Puffer’s statement that “[it] is a core activity in organised knowledge creation, as all academic disciplines require definition for the proper identification of their subject in order to determine what is and is not part of the field and also how field-specific knowledge objects are circumscribed and related to each other” (2015: 36). The quote also emphasizes that *DEFINE* has a strong connection with the other functions, in this case specifically drawing attention to the overlap with *CLASSIFY*.

Dalton-Puffer’s (2015: 36) description of *DEFINE* highlights that due to the function’s overall importance in academic discourse, it has also received the most attention in research of all of the CDFs. Hopf and Hoffmann (2015: 26) name this as one of the reasons for the low number of elements populating this CDF category in comparison to the others (only 3 members), although they also point out that this can be ascribed to *DEFINE*’s strong interconnection with other CDFs. Trimble (1985: 75) also refers explicitly to the integration of classification and description into *DEFINE*. Evidently *DEFINE* is a broad CDF, which can vary greatly in its performance. Consequently, a precise description of the function is necessary, in particular its use specifically in mathematics.

Summarizing the typical characteristics of definitions, Dalton-Puffer (2015: 36) names the two terms *definiendum*, which names the object to be defined, and *definiens*, which is the related superordinate term or class. In the *Introduction to Logic*, which investigates the use of language in mathematics in detail and will be used as a main source to present the mathematical perspective on *DEFINE*, Copi, Cohen, and McMahon (2011: 79) also refer to *definiendum* and *definiens* with two minor differences:

1. The authors stress that both the *definiens* and *definiendum* describe symbols and write that “what we *define* are always *symbols*”.
2. *Definiens* is described as “a symbol or group of symbols that is said to have the same meaning as the *definiendum*”.

An interesting contrast is that in the above definition there is no mention of a superordinate term or class, so rather denoting a hierarchical relationship, the mathematical view of *definiens* is one of equality. Copi, Cohen, McMachon (2011: 94) later describe a class-subclass structure of knowledge, but it is important to highlight that the concept of equality of great importance in mathematical definitions.

A commonly used conceptual framework for definitions is presented by Trimble as the equation “*Species=Genus+Differentia*” (1985: 75-76). Trimble’s formulation refers concretely to the scientific context giving an example from biology, but the model can also be applied to the mathematical field.

Copi, Cohen, and McMahon describe this approach as "definitions *per genus et differentia*" and give a specific example of this type of definition with the prime numbers (2011: 94-95):

> A prime number is any natural number greater than one that can be divided exactly, without remainder, only by itself and one. [...] In the definition of prime numbers just given, the genus is the class of natural numbers greater than one: 2, 3, 4, ... and so on; the specific difference is the quality of being divisible without remainder only by itself or by one: 2, 3, 5, 7, 11, ... and so on.

As is evident in the example above, such types of definitions can be very comprehensive in the structured body of knowledge of mathematics. In order to avoid terminological confusion, henceforth Trimble's (1985: 76) adapted equation of "T=C+D", where T refers to term, C to class, and D to difference, shall be used for such types of definition. Conceptualizing definitions through such an equation also simplifies the coding process as it makes them easy to identify, and an example is shown in Example 2 below in which the teacher and student discuss the positional relationship of two lines in two-dimensional space:

Example 2: Definition of the term "identical"

> T: And then the third case (.) The third case is that they [the lines] are parallel and (2) are, if they are parallel and on top of each other, we call them=
> Sm: =one line.
> T: Yeah, we call them identical.

In Example 2 the definition of identical when referring to the relationship of two lines can be structured in the following equation:

$$Identical = parallel + on\ top\ of\ each\ other$$

According to Trimble, definitions given in this format can be classified as simple definitions, and he categorizes them into three types according to the information given (1985: 75-80):

1. Formal definition: information on the term, class, and difference is given
2. Semi-formal definition: information on the term and difference is given (the class is often obvious in context)
3. Non-formal definition: the term is given in combination with a synonym or antonym

The non-formal definition is also outlined by Copi, Cohen, and McMahon as a "Synonymous definition" (2011: 92). This type of definition is of particular relevance in mathematics as in contrast to other subjects, in which predominantly synonymous words or phrases are presented to define a term, in mathematics, symbols and graphs can also be used to infer meaning.

Formal definitions according to Trimble can also be categorized according to the structure of the definitions as presented by Widdowson (1979: 56), who differentiates between nominal and real definitions. The overall framework for definition is consistent with that described above, although

Widdowson uses the terms “concept” and “characteristics” instead of “term” and “difference”. The structure of real and nominal definitions is shown in Figure 12 below (Widdowson 1979: 57):

| | | | |
|---|---|---|---|
| real definitions | concept | *is defined as*<br>*may be defined as* | class + characteristic |
| nominal definitions | class + characteristic | *is known as*<br>*is called* | name of concept |

**Figure 12 Real and nominal definitions according to Widdowson (1979: 57)**

As noted by Hopf and Hofmann (2015: 31), the two structures allow the speaker to emphasize different aspects of the definition. In real definitions, the new term forms the focus of the sentence, while in nominal definitions, the speaker highlights the characteristic which sets the class apart.

The definition of “identical” as presented previously in Example 2 constitutes a realization of a nominal definition as the class and characteristic (“parallel” + “on top of each other”) are discussed first, followed by the name of the concept, “identical”. A real definition is shown below in Example 3:

Example 3: Real definition

T: They [The irrational numbers] are all the real numbers that are not=
SX: =rational.

Example 3 shows a real definition as first the concept is presented followed by the class and characteristic. This information can also be adapted to Widdowson’s framework as presented below in Figure 13:

| | | | |
|---|---|---|---|
| real definition | The irrational numbers | *are defined as* | real numbers +<br>not rational |

**Figure 13 Example of a real definition adapted to Widdowson (1979: 57)**

In addition to simple definitions, Trimble (1985: 81) also names three types of complex definition: stipulation, operational, and explication. In the context of this thesis, the mathematical stipulation is of particular importance, and Trimble writes that it “is used mostly to identify the symbols in a formula or an equation to set values to a variable” (1985: 81). Copi, Cohen, and McMahon also describe the stipulative definition in the mathematical context, giving the following example: “The prefix ‘zetta-’ has been stipulatively defined as the number equal to a billion trillions ($10^{21}$), and the prefix ‘yotta-’ as the number equal to a trillion trillions ($10^{24}$)” (2011: 80). A concrete example of a stipulative definition in mathematics teaching is given in the dialogue shown below taken from the audio recordings:

Example 4: Passage with stipulative definitions

> T: That's correct (.) Two *x* plus five (.) Wonderful (.) Ok, and then if you turn the page please (.) The equation *y* equals *m*-*x* plus *c* (.) What is *m*-*x* plus *c*? [Sm]?
> Sm: ***m* is the gradient**.
> T: ***m* is the gradient and *c* is the**=
> Sm: =***y*-axis intercept**.

As can be seen in Example 4 the two variables *m* and *c* are both defined in the overall context of the linear function (*m* – gradient, *c* – y-axis intercept).

The second complex definition introduced by Trimble is the operational definition, which is described by Copi, Cohen, and McMahon as explaining a term by "tying the *definiendum* to some clearly describable set of actions and operations" (2011: 93). This type of definition is also of great importance in mathematics as terms are very frequently linked to concrete actions with the simplest examples being the four basic arithmetic operations: addition, subtraction, multiplication, and division. Kenney emphasizes this in the following passage (2005: 4):

> people tend to lump content and process together when discussing mathematics, calling it all mathematics content. However, it is vitally important to maintain a distinction between mathematical content and process, because the distinction reflects something very significant about the way humans approach mental activity of any sort. All human languages have grammatical structures that distinguish between nouns and verbs; these structures express the distinction between the objects themselves and the actions carried out by or on the objects

Kenney clearly sets operational definitions apart from the other types, highlighting that this differentiation is critical to a complete understanding of mathematics, and he also draws a comparison to the distinction between "verbs" and "nouns". The final complex definition outlined by Trimble is explication, but as its application is limited in the mathematics, it will not be described in any greater detail.

In addition to the extensive possible realisations of *DEFINE* listed above, Kröss (2014: 35) makes an adaptation to the original framework adding a new CDF type *DEFINE-TRANSLATION* to the original seven functions. Translating into students' first language can be a valuable method to communicating meaning in CLIL classrooms, and this is emphasized in Wilhelmer's summary of the main findings of her study of CLIL mathematics classes: "There is no need to exclusively stick to the L2, as the use of the L1 often acts as a support and facilitates students' understanding" (2008: 106). Kröss (2014) maintains that *TRANSLATION* in itself does not fit into the conventional structure of the types of definitions, and consequently she creates a further CDF type. Hopf and Hofmann (2015) also incorporate the *TRANSLATION* function into their framework, but they assign it to the CDF type *DEFINE*. However, Hopf and Hofmann also investigate the elements of the different CDF types in detail, so *TRANSLATION* is also studied in isolation. As this study will only research the use of the seven types of CDF without considering the elements of each function, Kröss' (2014) approach of creating a further CDF type

*DEFINE-TRANSLATION* will be adopted. This will provide greater insight in the use of *TRANSLATION* in CLIL classrooms.

### *DESCRIBE*

In their characterizations of this function, both Dalton-Puffer (2015) and Kröss (2014) refer to OED definition of *describe* in its "ordinary current sense" as given in the entry below:

*to describe*

> to set forth in words, written or spoken, by reference to qualities recognisable features, or characteristics marks; to give a detailed or graphic account of

The first important aspect of the definition is that *describing* omits any subjective judgement or evaluation, and in consequence it should be as objective as possible. This perspective is echoed by Copi, Cohen, and McMahon (2011: 64-65) who, although they do refer specifically to *describing*, introduce the *informative function* of language as the main focus of attention in mathematics. Secondly, the entry states that *describing* can be not only be realized both in spoken and written form, but also through graphic illustrations. This is particularly relevant in the context of mathematics as symbols, graphs, and also diagrams are regularly used to depict mathematical concepts and can certainly lead to greater student understanding.

Drawing on previous work by, among others, Widdowson et al. (1979) and Trimble (1985), Kröss (2014: 17-18) introduces four different categories for *DESCRIBE* based on the amount and kind of information given: (1) physical, (2) structural, (3) functional, and (4) process. Due to a lack of research into the role of the *describing* in mathematics classroom discourse, this framework will used as a starting point for discussing this CDF.

Of the first type, physical descriptions, Trimble writes that they give "the physical characteristics of an object and the spatial relations of the parts of the object to one another and to the whole and of the whole to other objects, if any" (1985: 71). He names the following typical characteristics included in physical descriptions: "dimension, shape, weight, material, volume, colour, and texture" (1985: 71). While at first glance physical descriptions may seem irrelevant when considering abstract mathematical concepts such as number sets, the "specific physical descriptions" outlined by Trimble occur frequently in the field of geometry as is evident in his examples, "at an angle of 45°" and "2cm out from the perimeter" (1985: 71).

The second type, structural description, is presented by Lackner (2012) in his analysis of discourse functions in CLIL history classes. He determines a strong similarity to physical descriptions, but states that structural descriptions specifically "express a part-whole relationship" (2012: 51). Furthermore, Lackner identifies typical two typical linguistic constructions used to describe such types of descriptions present below in Figure 14 (2012: 52):

**Structural description Type I**

| | | |
|---|---|---|
| Whole | *consists of* | Parts |
| | *is divided into* | |
| | *is made up of* | |
| | *includes* | |

**Structural description Type II**

| | | |
|---|---|---|
| Parts | *make up* | Whole |
| | *form* | |

**Figure 14 Two types of structural description adopted from Lackner (2012)**

Figure 14 has a similar framework to Figure 10 which shows the two different types classification, but it should be noted that the two types of structural descriptions refer to physical attributes, whereas the two types of classification order concepts according to intellectually constructed bodies of knowledge.

The third category of *DESCRIBE*, the functional description, broadly applies to devices, and according to Trimble the information either outlines (1985: 72):

1. The use or purpose of the device
2. The functioning of each of the main parts of the device

Trimble notes such types of description "is frequently associated with causality and result" (1985: 72).

As with the structural description, the functional description can also be performed in two different directions, as illustrated in Figure 15 adapted from Lackner (2012: 53):

**Functional description Type I**

| | | |
|---|---|---|
| *Whole/part* | serves to<br>is responsible for<br>performs the function of<br>controls<br>regulates | *function* |

**Functional description Type II**

| | | | | | |
|---|---|---|---|---|---|
| The<br>A<br>One | function<br>purpose<br>aim<br>objective<br>role | of the | *whole/part* | is to | *function* |

**Figure 15 Two types of functional description adapted from Lackner (2012)**

As functional descriptions are primarily concerned with devices, which are not a primary focus of mathematics teaching, it may be assumed that this type will not frequently occur in mathematics classes. This is in stark contrast to the fourth and final category of description, namely the process description.

Trimble refers to process descriptions as “a series of steps or stages that are interrelated in that each step (but the first) is dependent on the preceding step and that all steps lead toward a definite goal” (1985: 72). He also emphasizes that while process descriptions can be viewed as a type of functional description, they should be considered separately. Trimble also points out that “[o]ften a process description is a series of instructions” (1985: 72). Such types of description can be presumed to be relatively frequent in mathematics education, where fixed algorithmic processes are often used to determine solutions. Buchbinder, Chazan, and Capozolli present an example from the mathematics textbook *Algebra 1* in which clear instructions are given on how to solve a linear equation (Charles et. al. 2015: 105, quoted in Buchbinder, Chazan & Capozolli 2019: 55):

> Step 1. Use the Distributive Property to remove any grouping symbols. Use properties of equality to clear decimals and fractions.
> Step 2. Combine like terms on each side of the equation. [Steps 1 and 2 bring the equation to the form $ax + b = cx + d$ and are not necessary if the equation is already given in that form.]
> Step 3. Use the properties of equality to get the variable terms on one side of the equation and the constants on the other.
> Step 4. Use properties of equality to solve for the variable.
> Step 5. Check your solution in the original equation.

The above instructions form a prototypical example of a process description as the student is given a step-by-step guide to solving linear equations.

A set of instructions as given in a process description will be characterized by certain linguistic features, in particular discourse markers. Gillett, Hammond, and Martala (2009: 123) identify typical linguistic units used to structure process description, which Lackner compiles into a general overview as shown in Figure 16 (2012: 54):

| | |
|---|---|
| Step I | First (of all), To begin with, The first step is |
| Step II | Secondly, Then, After ... hours, days, years, The next step, Next, Subsequently |
| Step III | Finally, In the end, Lastly, Later, In the last stage |

**Figure 16 Process description adopted from Lackner (2012: 54)**

Figure 16 gives a complete overview of the linguistic markers used in process descriptions. As in mathematics, the temporal aspect of process descriptions is largely irrelevant, it can be assumed that the phrases “After ... hours, days, years” will not be used, but there are other mathematical contexts in which such linguistic markers can be introduced. For instance, in the topic “functions”, a certain variable is often dependent on “time”, so a task may require students to “Determine how long it takes for ball to fall 45m” using the function $s(t) = 5t^2$ where $t$ expresses time in seconds and $s(t)$ the distance an object has fallen after $t$ seconds. An answer to this task could then be phrased as “**After 3 seconds**, the ball has fallen 45m”.

The above discussion shows that *DESCRIBE* is a core component of teaching, but there is some uncertainty about the distinct classification of this function from the other CDFs. In her initial account of the CDF construct, Dalton-Puffer notes that “Describing may be involved in *EXPLAIN* or *REPORT* – and to a small extent even in *DEFINE* – but there will also be instances of *DESCRIBE* which are neither of the three but something in their own right. Kröss also points out that *CLASSIFY* can be viewed as a subcategory of *DESCRIBE* (2014: 20). This ambiguity in categorizing the CDFs must be considered in the analysis of the data, and Dalton-Puffer writes that large-scale research in still required to clarify the relationships of the different CDFs.

### *EVALUATE*

The OED definition for the verb *evaluate* describes it as “to work out the ‘value of (a quantitative expression)”. While this definition is applicable to the mathematical context, it does not reflect the meaning of *EVALUATE* as a function, and Kröss (2014: 21) considers this in her analysis by examining the definition of *judge* instead. Furthermore, Kröss points out that a core characteristic, reflected in the analysis of *judge*, which sets *EVALUATE* apart from the other CDFs is that it involves some form of subjective judgement by the speaker. This is also reflected in the different members populating the *EVALUATE* category: *evaluate*, *judge*, *argue*, *justify*, *take a stance*, *critique*, *recommend*, *comment*, *reflect*, *appreciate* (Dalton-Puffer 2013: 235). The list clearly illustrates that *EVALUATE* has a greater number of realisations relative to the other functions, and it also highlights the subjective nature of the function as each of the verbs indicates some form of personal judgement. This aspect is well summarized by Dalton-Puffer who determines the underlying communicative intention of *EVALUATE* to be "I tell you what my position is vis a vis X" (2013: 234). In her later publication, Dalton-Puffer also adds that in the function forming a judgement is "based on evidence, [...] previous knowledge and values" (2015: 41).

As mathematics is generally considered a "hard" science with a rigorously structured body of knowledge, one may jump to the conclusion that subjective judgements are misplaced. Consequently, it might be assumed that *EVALUATE* will not occur frequently in mathematics teaching. However, such an assumption fails to recognize two important factors. Firstly, students need to acquire the ability to evaluate mathematical models and approaches. This is emphasized by Linneweber-Lammerskitten who as an example for a cognitive skills names "[e]valuating the reasonableness of a mathematical solution in the context of a real-world problem" (2012: 16).

The second facet of *EVALUATE* which takes on great importance in mathematics when considered from the teacher's perspective is giving informative feedback on students' approaches and working. This aspect of *EVALUATE* is not considered by Dalton-Puffer (2013 & 2015) in her original conceptualization of the CDF construct. However, Hopf and Hofmann introduce such 'student evaluations' into their CDF framework, although they also note that they may be deemed irrelevant "given their little informative value" (2015: 45). This seems not to be the case in mathematics, as teacher evaluation of student answers forms an important part of classroom discourse. This is highlighted by Franke, Kazemi, and Battey in their characterisation of mathematics classroom practice in which they write that "[m]ost U.S. mathematics classrooms maintain an initiation-response-evaluation (IRE) interaction pattern" (2007: 229). Consequently, it may be assumed that such occurrences of *EVALUATE* will be relatively frequent in the data and should not be ignored.

A problem that arises when taking teacher evaluations of student responses into account is the limits of what can be classed as a realisation of *EVALUATE*. Obviously, simple expressions which give feedback on students' answers, such as "correct" or "that's right", could be categorized as evaluations. However, such simplistic linguistic phrases seem to lack the complexity required to be categorized as the cognitive thinking skill described in the CDF *EVALUATE*. Dalton-Puffer's description of *EVALUATE* provides some clarity in this regard as she writes that a realisation of the function will include "the evidence, criteria, standards or reasons which support the evaluation that is being made" (2015: 42). Consequently, in the data analysis only evaluations which include this additional information will be categorized as occurrences of *EVALUATE*.

According to Mautner (2019: 140), evaluations can be classified by four main variables (translated by Kröss 2014: 22):

1. positive versus negative
   *Does the realiser express a positive or a negative attitude towards the person/object/etc. evaluated? Do they consider it good (valuable) or bad (valueless)?*
2. certain vs. uncertain
   *Does the realiser seem to be convinced of their evaluation or can a certain degree of doubt be detected? Does the realiser distance themselves from their evaluation?*
3. important versus unimportant
   *Does the realiser consider something important and draws the audience's attention towards it or do they consider it unimportant and try to distract from it?*
4. direct vs. indirect
   *Does the realiser attempt to make the evaluation being easily identified as such or do they prefer it being detected by its linguistic and/or social context?*

Mautner points out that the dimensions are not to be understood as binary but rather as endpoints of an axis along which evaluations can be located (2019: 141). While Mautner's model provides a useful framework for categorizing evaluations, a detailed analysis of the realisations in the recordings goes beyond the scope of this thesis.

Finally, a discussion of *EVALUATE* would be incomplete without briefly highlighting the power imbalance present in the educational context, and the implications of this for any form of evaluation. Both Dalton-Puffer (2015: 43) and Hopf and Hofmann (2015: 45) describe this inequality interwoven into classroom discourse. Teachers determine the content and structure of the classes, and they also ask the most questions. Furthermore, teachers are also responsible for grading each of the students, which can provide a sense of power as grades can often greatly impact students' school careers. As evaluations always involve some form of subjective judgement, it can be assumed that students will be tentative in voicing their opinions as improper statements may induce undesired consequences from the teacher. Therefore, it is expected that the data will show only few realisations of *EVALUATE* from students.

### *EXPLAIN*

Dalton-Puffer introduces three different components to the definition of the word *explain* taken from the OED (2015: 44):

1. *Explain 1*: To make sth. plain or intelligible; to clear of obscurity or difficulty; to give details of or to unfold (a matter).

2. *Explain 2*: To give an account of one's intentions or motives.
3. *Explain 3*: To make clear the cause, origin, or reason of.

Due to its very general nature, Dalton-Puffer omits *Explain 1* from the CDF construct, pointing out that "all the CDF functions in their totality could be said to contribute to 'explaining' in the sense of *Explain* 1" (2015: 44). Consequently, explaining as understood as a CDF can be realised through *Explain 2* or *Explain 3*, although these two types of explanations are also very different in nature. According to Dalton-Puffer (2015: 44), *Explain 2* seeks to determine the underlying human intentions for events, an area which is very open to interpretation and may lead to different results, and in consequence this type of explanation will be frequently used in the humanities, for instance history (2015: 44). In contrast, *Explain 3* is linked to the construction of knowledge in the hard sciences which provide "exclusively deductive explanations of phenomena" (Dalton-Puffer 2015: 44). Explanations in mathematics will primarily take the form of *Explain 3*, as understanding is formed through logical reasoning and deduction.

*Explain 3*, as presented by Dalton-Puffer (2015), concurs with the definition for *Explanation* given by Copi, Cohen, and McMahon: "A group of statements from which some event (or thing) to be explained can logically be inferred and whose acceptance removes or diminishes the problematics character of that event (or thing)" (2011: 615). Their definition equally stresses the importance of logic in developing an explanation, but the final phrase of the sentence also highlights that an explanation also serves to clarify misunderstandings. An example of a teacher clarifying a student misconception in the mathematical context is shown in the passage below in which a student asks a question relating to the relationship of two lines in two-dimensional space:

Example 5: *EXPLAIN* used to clarify a misunderstanding

> Sm: Herr Professor?
> T: Yes.
> Sm: Wie können sie parallel sein, wenn sie sich schneiden? [How can they (two straight lines) be parallel if they intersect?]
> Sm: Sie können entweder parallel sein oder sich schneiden. [They can either be parallel or intersect]
> Sm: Achso.
> T: Sie können parallel sein, dann gehen sie aber auseinander, da gibts einen schönen Fachbegriff, der ist parallel und disjunkt.

Example 5 shows a passage in which the teacher rectifies a student misunderstanding. The student asks how two lines can both be parallel and intersect, and the teacher rectifies this confusion by explaining that they can either be parallel or intersect. Such instances of *EXPLAIN* are of particular relevance in mathematics, a subject in which students often possess a variety of misconceptions, and often teachers need to provide numerous explanations before a topic is fully understood.

The function *EXPLAIN* in the context of this thesis is well summarized by its underlying communicative intention: "I give you reasons for and you the cause/s of X" (Dalton-Puffer 2013: 234).

The above discussion has shown that explaining in mathematics involves providing insight into the different steps of a logical chain to arrive at a certain conclusion. In her publication on the discourse of explaining in mathematics teaching, Erath presents an overview of a categorization into three different types of explaining applied to the mathematical context (translated from Erath 2017: 10):

1. EXPLAIN-WHAT: in this type of explanation, concepts are assigned to the appropriate mathematical terminology
2. EXPLAIN-HOW: explaining how something works refers to specific procedures
3. EXPLAIN-WHY: these types of explanations take the form of formal proofs

The overview allows for a further classification of different types of *EXPLAIN*. However, it is important to note that in mathematics classroom, the third category, EXPLAIN-WHY, will usually not take the form of formal mathematical proofs, but rather of a chain of logically formed deductions.

Widdowson (1979b: 108) presents a similar conceptualization of explaining of the relation of cause and effect as a chain of reactions, captured in the image presented by Hopf and Hofmann shown in Figure 17 (2015: 49):

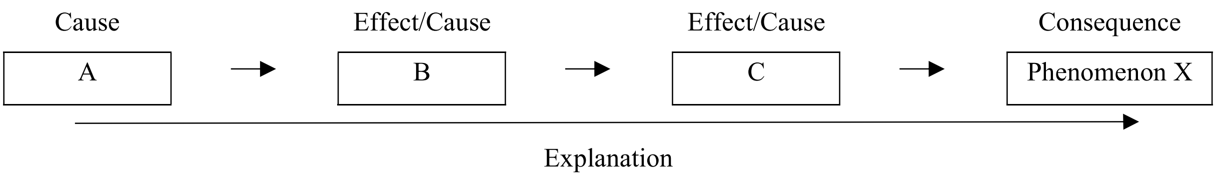



**Figure 17 *Cause and effect* from Hopf and Hofmann (2015: 49) adapted from Widdowson (1979b: 108)**

Figure 17 illustrates the logical chain of deduction in an explanation used to arrive at a conclusion, and this model is a useful framework for conceptualizing explanations as a step-by-step process.

Erath's (2017) categorization of the different types of explanation also highlights a further issue, namely the overlap with other CDFs. The second type of explaining, EXPLAIN-HOW, for instance, is very similar in nature to process descriptions of the CDF *DESCRIBE*. In this case it would seem that process descriptions form part of explaining how a certain procedure works, so *DESCRIBE* is contained within *EXPLAIN*. Furthermore, the first type of explaining, EXPLAIN-WHAT, which links an idea to the appropriate mathematical term or symbol, has a strong overlap with the stipulative definition described in *DEFINE*. In this instance, again *DEFINE* forms part of *EXPLAIN* as illustrated in Table 5:

| *DEFINE*: stipulative definition | *EXPLAIN*: EXPLAIN-WHAT with embedded *DEFINE* |
|---|---|
| The symbol ℚ is used to describe the set of rational numbers. | The symbol ℚ is used to describe the set of rational numbers. Rational numbers are all numbers that can be represented as fractions. and a fraction can also be understood as a division of two numbers, of which the result is called "quotient" – Q for Quotient is the result of a division, hence ℚ |

**Table 5 Example of *DEFINE* and *EXPLAIN***

As is evident in Table 5, the realisation of *EXPLAIN* gives significantly more information than *DEFINE* and seeks to build understanding of the term. Consequently, in this example *DEFINE* forms a part of *EXPLAIN*. This strong interconnection with the other CDFs is an area that must be considered carefully in any application of the CDF construct, and clear boundaries must be set in order to provide for consistent analysis.

### *EXPLORE*

Dalton-Puffer chooses the label *EXPLORE* as the overarching CDF type to encapsulate the meaning of its various members, namely *hypothesize*, *speculate*, *predict*, *guess*, *estimate*, *simulate*, and *take other perspectives* (2013: 235). Closer inspection of the members reveals the common core idea of *EXPLORE* which is to develop an informed judgement of possible future outcomes under the present given circumstances, and Dalton-Puffer stresses the importance of the function in her previous work on discourse in CLIL classrooms, albeit at the time she used the term *hypothesize* (2007). The overall communicative intention of the function is well captured in the statement: "I'm talking about something which is not in the here and now, and which is not past fact either. I do not have conclusive evidence for what I say but it can serve me/us as a basis for further reasoning" (Dalton-Puffer 2015: 46).

Kröss emphasizes the relevance of *EXPLORE* in the context of physics in which students regularly have opportunities "to predict outcomes, hypothesise about potential explanations, make guesses and estimations, simulate phenomena, etc." (2014: 26). While such characterisation cannot be directly transferred to the mathematics, which does not include conventional scientific experiments as are found in physics, there are numerous possibilities to realise *EXPLORE* in the subject. The is highlighted in Linneweber-Lammerskitten's (2012: 27) description of language in mathematics in which "Exploring/processing/documenting" is listed as a macro function and both "Hypothesizing" and "Predicting" are named as micro functions. Furthermore, the text also describes the mathematical exploration which is structured in a similar fashion to experiments in physics with students being required to make conjectures on possible results (2012: 29-30).

Lim et al. go into greater detail on the role of prediction in mathematics teaching and describe three main benefits (2010):

1. Student's predictions can reveal their misconceptions.
2. Prediction plays an important role in reasoning.
3. Prediction fosters learning.

An important aspect of this conceptualization of *EXPLORE* in mathematics is that questions are relatively open and allow students to experiment with a variety of different methods. This is further illustrated in the following example (Lim et al. 2010: 597):

> Asking students to predict has an advantage over asking students to find an answer. [...] When asked to find the largest fraction among 99/100, 6/7 and 15/16, students can instrumentally convert each fraction into a decimal or into its equivalent fraction with a common denominator, and then compare the adjusted numerators. When asked to predict, students can think *relationally*.

This example shows that having students *EXPLORE* opens up a variety of different pathways to arriving at a solution and develops cognitive thinking skills which stands in contrast to having students adhere to a fixed procedure.

Viewed from the linguistic perspective, realizations of *EXPLORE* require the use of relatively complex areas of the English language. Dalton-Puffer specifically mentions "modal verbs (e.g. may, will, can), modal adverbs (e.g. maybe, perhaps, possibly) and dependent clauses with conditional conjunctions (mostly if)" (2015: 47). Furthermore, in her previous discussion of *hypothesizing*, Dalton-Puffer presents an overview of verbs and phrases commonly used to introduce instances of the function, as presented in Table 6 and Table 7 below (2007: 160-161):

| | |
|---|---|
| assume | propose |
| guess | speculate |
| hypothesize | suggest |
| imagine | suppose |
| predict | |

**Table 6 Lexical verbs introducing *EXPLORE* episodes (Dalton-Puffer 2007: 160)**

| | |
|---|---|
| let's think/say/assume/imagine | what would your predictions be? |
| (so) what would happen (if) | what would you propose |
| what will happen if | what would you do if |
| what happens if | anyone wanna take a guess? |
| can you predict | |

**Table 7 Phrases introducing *EXPLORE* episodes (Dalton-Puffer 2007: 161)**

The two tables highlight the complexity in language required to express the function, especially when considering that in the CLIL environment students use a second language. Dalton-Puffer notes that this challenge may cause learners to avoid using *EXPLORE* altogether. Furthermore, students accustomed to a traditional mathematical learning environment in which answers are either "right" or "wrong" and may be generally reluctant to engage in predictions.

Overall, *EXPLORE* may be challenging for learners to realize. However, the function holds seemingly holds enormous potential for CLIL mathematics for two main reasons. Firstly, *EXPLORE* presents an opportunity for teachers to introduce students to a wide range of new verbs and phrases as well as provide numerous instances for authentic practice. Secondly, viewed from the mathematical perspective, exploring allows students to experiment with different methods in solving a mathematical problem. Its advantage is well encapsulated in Lim *et al.*'s statement that "[w]hen students predict, as opposed to meticulously working through the steps, they are psychologically relieved from the need for precision and certitude" (2010: 597)

### *REPORT*

According to Dalton-Puffer, the final CDF *REPORT* describes communication of "what happened, when, who did it and to whom and under what circumstances" (2015: 49). The core meaning of this CDF type also becomes clearer when reviewing its various members: *report*, *inform*, *recount*, *narrate*, *present*, *summarize*, *relate* (Dalton-Puffer 2013: 235). It is evident is that at the core of *REPORT* is the intention of giving information, and this is summarized in the statement: "I tell you sth. external to our immediate context on which I have a legitimate knowledge claim" (Dalton-Puffer 2013: 234).

Kröss notes that in the context of physics classrooms, *REPORT* will predominantly refer to the process and result of an experiment (2014: 29). As is also the case with *EXPLORE*, this manner of reporting can also be transferred to mathematical explorations in which students share information on how they arrived at their solution. This viewpoint is consistent with Linneweber-Lammerskitten's (2012: 27) findings in which "Reporting" is listed as both a macro and micro function. He also presents the following phrase as a possible linguistic resource in displaying discursive competence: "In the following, I will write/*report* about..." [my emphasis] (2012: 30). Clearly, *REPORT* is an important function in mathematics teaching; however, as is the case with *EXPLORE*, the frequency of realizations of the function will also depend greatly on the style of mathematics teaching implemented in the classroom.

Hyland (2004: 27) differentiates between three types of reporting depending on what is being referred to:

1. Research Acts: referring to real-world activities, which occur in statements of findings (*observe, discover, notice, show*) or procedures (e.g. *analyse, calculate, assay, explore*)
2. Cognitions Acts: concerned with mental processes (*believe, conceptualize, suspect, view*)
3. Discourse Acts: involve verbal expression (*ascribe, discuss, state*)

Hyland's categorization does not fully encapsulate the meaning of *REPORT* as a CDF, but it does indicate possible links to other functions, for example "*observe*" may involve a realization of *CLASSIFY* or *DEFINE*. In the case of mathematics, it can be presumed that predominantly the first type of reporting, Research Acts, will occur as students will be tasked with recounting mental procedures of determining solutions. Hyland (2009: 28) confirms this assumption stating that the hard sciences show a higher usage of verbs exhibiting Research Acts, although he does not refer explicitly to mathematics.

## 4.4. Previous findings

This section outlines some of the previous research on the different CDFs, drawing on the findings of three diploma theses investigating CDFs in different subjects, all of which studied CLIL lessons in Austria and were supervised by Dalton-Puffer. Their results provide some useful insight into the analyses using the CDF framework, but it should be noted that the implications for this thesis are limited as they studied CLIL implemented in subjects very different in nature to mathematics. Consequently, it can be expected that the use of the types of functions will differ to the previous works.

The first thesis written by Kröss (2014) investigates the use of the CDFs in upper secondary physics lessons. Kröss (2014) introduces two important modifications to the CDF framework, which will also be used for the analysis of this thesis. Firstly, Kröss (2014: 36) establishes the concept of "moves" which are used to describe occurrences of a CDF within a passage coded as a different type of CDF. As described in section 4.3.1., the different types of CDFs have fuzzy boundaries and certain functions may be realized in the broader context of a different CDF. The introduction of the "moves" allows for an analysis of how the different types of CDF occur within each other. The second important adaptation to the framework, mentioned previously in *DEFINE*, is the introduction of a marker to code for translations (2014: 35). In a previous study of CLIL in mathematics, Wilhelmer (2008 :106), points out the value of using the L2 to enhance meaning and consequently it is critical to consider this in the analysis.

Kröss (2014) analysed data from six recorded lessons, and in total 95 CDF passages and 504 CDF moves were coded. The results indicate that realizations of CDFs are unevenly distributed with *DESCRIBE*, the most frequent function, occurring 25% of the time (2014: 46). In contrast, *CLASSIFY* and *EVALUATE* each constitute less than 4% of all realisations. Furthermore, the study shows that CDFs are predominantly realized through teacher and student interaction (59%), rather than by the teacher or students in isolation (2014: 52). In fact, only 6% of all CDFs were realized by students only, indicating that students required guidance throughout all of the lessons despite having received language instruction in English for a minimum of eight years.

Hopf and Hofmann (2015) investigated the distribution of the CDFs in CLIL biology lessons. They use the same basic framework as Kröss (2014) but also analyse the use of the sub-types of the different types of CDFs, for example instances of *DESCRIBE* were also categorized according to the type of description: physical, structural, functional, or process (2015: 74-75). While such an analysis provides greater detail into the specifics of the different types of CDF, it is beyond the scope of this thesis and will not be considered in the analysis. Although the realizations of CDFs in Hopf and Hofmann's (2015: 82) study are more evenly distributed than in Kröss' (2014) research, there is still a clear tendency to perform certain CDFs with *DESCRIBE* again being the most frequently used function (21%). At the other end of the scale, *CLASSIFY* and *EVALUATE* again both occur less than 13% than of the time, although in this case *REPORT* also falls into this category. In contrast to Kröss' (2014) results, Hopf and Hoffmann (2015: 89) find that CDFs are overwhelmingly performed by the teacher in isolation, while again only a very small percentage accounted for student only realization (7%).

The final thesis completed by Brückl (2016) also analysed a sample of six lessons, albeit in CLIL economics lessons. Brückl (2016) adopted the same coding scheme as Kröss (2014), although she avoids the term "moves" and describes instances of CDFs within another CDF as "embedded". Furthermore, following on Kröss' (2014) initial work in the area, Brückl (2016) also creates a coding tool for all realization of CDFs in German. Brückl's (2016: 55) results show similarities but also differences to the other two studies. While the two functions *CLASSIFY* (4%) and *EVALUATE* (5%) again both occur very rarely, *REPORT* (25%) joins *DEFINE* (26%) in being one of the two most frequently used functions (2016: 55). *DESCRIBE*, which was clearly the predominant CDF in both Kröss' (2014) and Hopf and Hofmann's (2015) thesis, occurs only 12% of the time (2016: 55). These results indicate that there are certainly differences in the distribution of the CDFs according to the subject area. Both Kröss (2014) and Hopf and Hofmann's (2015) studies investigated a scientific subject, so it can be presumed that there would be a strong overlap in CDF use. In contrast, Brückl's (2016) analysis focuses on CLIL in economics, which, as a very different area of academic study than the natural sciences, can be expected to require different CDFs.

Brückl's (2016: 72) findings on the distribution of CDFs according to realizers also contradict previous results as in her sample collaborative teacher-student realizations occur the least with only 18%. Furthermore, student only and teacher only realizations of CDFs are relative evenly distributed accounting for 37% and 45% respectively of all occurrences. While the difference to previous results may be caused by the subject under investigation (economics), care should be taken in making generalizations, as these discrepancies could also be the result of differing styles of teachings or even inconsistencies in coding. Consequently, more research is needed into the distribution of CDFs in different subjects.

Dalton-Puffer (2018) presents the collected results of all the studies introduced above as well as two others in her publication aiming to provide empirical backing for the CDF construct. One main finding from all the results is that CDF indeed occur in naturalistic CLIL lessons, and consequently are an appropriate methodology to be used for discourse analysis (2018: 15). With regard to the occurrence of individual CDFs, *DESCRIBE* is the commonly realized CDF in four of the five studies although the exact frequency differs in different subjects – 35% in physics and 21% in biology (2018: 16). Overall, it can be observed that the distribution of the different types of CDFs differs from subject to subject. An overview of who realizes the CDFs shows that this depends on teaching style as well as the nature of the subject. Dalton-Puffer points out that, in contrast to the humanities, the natural sciences, physics and biology, tend to be more teacher-centred, hence CDFs are more frequently realized by the teacher rather than the students (2018: 20).

The results of previous work provide some valuable information for the research of this thesis. Firstly, the findings presented above give the CDF construct a certain degree of empirical validity, as there are a significant number of studies which have successfully used it as a research tool. Furthermore, certain tendencies can be identified regarding the distribution of the different types of CDFs. *DESCRIBE*, for instance, occurs frequently in almost all studies, and the question then arises whether these findings will be replicated when analysing CLIL in mathematics. Overall, it can said that the previous work provides a theoretical and practical foundation on how to appropriately use the CDF construct as an analytical tool, but the fact that in this thesis it is being applied to a new subject, mathematics, means that new, different results can be expected.

# 5. Study design

As mentioned in previous sections, there has been some research conducted into the use of CDFs in CLIL classrooms. Theses by Kröss (2014), Hopf and Hofmann (2015), and Brückl (2016) in particular have informed the data analysis of this study. The findings of these three texts, along with two other publications, are collected and interpreted by Dalton-Puffer et al. (2018). Among others, the authors outline the following specific focus for future research into CDFs (2018: 27):

> In further studies it will, however, also be necessary to take account of subject-specific, typical realizations of functions that emerge from the characteristic practices of individual subjects. In such undertakings it would be highly desirable to work in interdisciplinary teams including subject education experts in order to secure the conceptual linkage between CDFs and the respective subject's understandings of knowledge and competences to be acquired and demonstrated.

In alignment with Dalton-Puffer's recommendation, the focus of this study is to investigate the subject-specific use of CDFs in naturalistic CLIL mathematics classrooms in order to gain insight into the interrelationship of language and mathematics. Furthermore, it is the hope of the author that the results of this thesis will form a foundation for further research seeking to formulate language-specific goals for CLIL implemented in mathematics, so CLIL teaching can continue developing in integrating the learning of language and content.

## 5.1. Research questions

Building on previous research into the CDF construct, this thesis will firstly adopt similar research questions to those originally proposed by Dalton-Puffer (2013: 241):

1. Which CDF types are realized in naturalistic mathematics classes?
2. What is the context in which the individual CDF types are realized?
3. Who realises them?

Additionally, expanding on work by Kröss (2014) and Brückl (2016), the analysis will also look at the interrelationship between the different types of CDF by investigating realizations of individual functions within broader CDF episodes. This focus is addressed in the following research question adopted from Brückl (2016: 31):

4. How are the cognitive discourse functions interactionally realized?

Finally, the fourth research question will address the use of the L1 and L2 in the CLIL mathematics classroom in order to gain a better understanding of the interwoven use of different languages in constructing meaning:

5. Which language(s) are CDFs realized in and how are different languages used to construct meaning?

This fifth research question also aims to provide some insight into the triangular interrelationship of the L1, L2, and the language of mathematics, as discussed previously in chapter 3.

The findings related to answering these four questions are expected to create an initial characterisation of classroom discourse in CLIL mathematics classroom and in consequence provide a first step in the direction of formulating explicit language learning aims, so as to help teachers incorporate explicit language elements into their teaching. Additionally, the third research question aims to expand the amount of empirical research available on the interrelationship of the CDFs, so the construct can be further refined and validated.

## 5.2. Methodology

In order to answer the research questions regarding the use of CDFs in naturalistic CLIL mathematics classrooms, a qualitative analysis of audio recordings of seven lessons was conducted. A significant challenge in the initial phase of this study was that there were no available recordings in the database of the University of Vienna to analyse. This stands in contrast to the work of Kröss (2014) and Brückl (2016) who were both able to use partly transcribed recordings from previous research. A wide range of different communication channels were pursued in finding a teacher of CLIL mathematics classes who was also willing to allow having their lessons recorded, and this initially proved more difficult than expected. Feedback from one teacher indicated that since the introduction of the centralised Matura, the final school examination in which mathematics must be taken by all students in German, in 2014/2015, there is a general reluctance to teach mathematics through a second language. However, after some time a teacher who was willing to participate in the study was found. In order to comply with all legal regulations regarding data collection in school classrooms, two consent forms, adapted from a previous dissertation by Berger (2013) shown in the Appendix in section 9.3., were issued to both the parents of the students and the headmaster of the school in advance. At this stage, it is also important to note that the decision to gather only audio and not video recordings was made in consideration of the complex Austrian legal framework, which makes it extremely difficult to gather any video data in schools.

Originally, six recordings were planned to be conducted during the months of May to June 2019. However, due to certain administrative issues, the recording sessions had to be split with the first four being completed during this time period, while the rest were carried out in the next school year between September and October 2019. Furthermore, as one of the recording sessions of a double lesson completed in June 2019 towards the very end of the school year yielded only little valuable data, a decision was reached with the teacher to complete a seventh recording. The recordings in the lessons were completed with two *Zoom H2N Handy Recorders*, which were supplied by the Department of English and American Studies of the University of Vienna.

The data from the recordings was transferred to a computer and then transcribed using *Express Scribe Transkriptionssoftware*, which allowed the audio files to be easily paused, rewinded, and played more slowly. The audio data was transcribed according to VOICE (Vienna Oxford International Corpus of English) conventions [2.1.], although it should be noted that certain aspects, such as intonation, pauses, and emphasis, were not taken into consideration during the transcription process as these factors are not relevant for the research focus of this thesis. In addition, the names of students were omitted throughout to ensure anonymity. A minor adaption made to transcription conventions was to write variables, which often occur in the mathematical context, in italics. Finally, the recordings were imported to the data management software ATLAS.ti8 and were then coded according to the framework presented in section 5.4. focussing specifically on the two areas highlighted in the research questions – CDF type and realiser. Finally, notable passages of the CDF episodes were highlighted and commented upon in the ATLAS.ti8 software in order to provide an overview of typical features of the CDFs in the mathematical context.

## 5.3. Data overview

In total, seven lessons each taught by the same teacher were recorded over two periods in different school years. The class which was an 8$^{th}$ grade during the school year 2018/2019 and a 9$^{th}$ grade during the school year 2019/2020 remained overwhelmingly the same throughout the two recording periods with only a few students leaving and joining the class during the summer break. The teacher was the same throughout all of the lessons. In Austrian schools, lessons are scheduled in slots of 50 minutes. However, the actual teaching and subsequently the recording time varied due to different administrative issues (e.g. teacher arriving shortly after bell rings, students gathering books and material, students settling down from break). Furthermore, it should be noted that the teacher was not only the mathematics and Spanish but also the class teacher of the group, and as a result most lessons featured some sort of administrative talk, which was not considered in the data analysis.

The school, located in the greater Vienna region, is a "Gymnasium" which stretches over eight years from grade 5 to grade 12 at which point students complete their final examinations, the Matura. The school offers additional English in class through the program *Englisch als Arbeitssprache* (EAA) which can be roughly translated to "English as a working language". In this programme, certain subjects, depending on the grade, are occasionally taught through English and sometimes supported through native speakers. While officially there are no formal extra qualifications required to teach CLIL, the teacher observed in this study has a diploma teaching degree from the University of Vienna for the subjects mathematics, English, and Spanish. Consequently, regarded from the perspective of the extensive discussion of CLIL in chapter 2., the teacher can be regarded as ideally suited for teaching CLIL as he/she has knowledge of both teaching the language (English) and teaching the subject (mathematics).

A general overview of the lessons recorded is presented in Table 8 below:

| Lesson code | No. of students | Grade | Topic | Comments |
|---|---|---|---|---|
| L1 | 19 | 4 | Linear functions: $y = k * x + d$ | Teacher uses pages copied from an English schoolbook |
| L2 | 25 | 4 | Linear equations in two variables | Native speaker assistant joins class for final 15 minutes. |
| L3 & L4 | 26 | 4 | Solving systems of linear equations. | Two lessons are merged to double lesson of 100 minutes. One guest student (English native speaker) is present. Teacher uses YouTube videos to present new content. |
| L5 | 21 | 5 | Determining mathematical expressions | Tasks from German schoolbook are used and translated into English |
| L6 | 20 | 5 | Closure and number sets | Teacher developed own worksheet with English tasks |
| L7 | 21 | 5 | "Definitionsmenge" & the overarching structure of mathematical expressions | Tasks were taken from German schoolbook |

**Table 8 Overview of lessons analysed**

A key issue that must be mentioned at this point is that there are no CLIL mathematics schoolbooks available to CLIL practitioners, and English schoolbooks do not adequately cover the Austrian curriculum. The teacher used a variety of different strategies to manage this issue, for instance using copies from English schoolbooks (L1), presenting English YouTube videos (L4), creating own worksheets (L6), or translating tasks from the Austrian schoolbook into English (L5). Teachers of CLIL in all subjects are regularly faced with the challenge of finding appropriate, authentic material and also managing the material in manner that aligns with the Austrian curriculum. As a consequence of these circumstances, German passages were also coded according to the CDF framework, as outlined in the next section.

## 5.4. Coding framework

The coding framework is based foremost on Dalton-Puffer's (2013) original CDF construct as described in detail in section 4.3., which outlines the seven different types of CDF. However, the application of the CDF framework in the various studies quoted in previous sections as well as the specific circumstances of CLIL in mathematics indicates the need for certain clarifications and adaptations.

### 5.4.1. Coding of CDFs in the CLIL mathematics classroom

The mathematics classroom presents a unique educational environment, and consequently, its classroom discourse differs significantly from other subjects which have already been studied using the CDF construct. Therefore, it is critical to clarify the coding procedure of certain CDFs in situations specific to mathematics classrooms to ensure consistency in the analysis. This section introduces some of these specific areas, so they can be adequately considered in interpreting any results.

Firstly, it is important to discuss how simple calculations fit into the CDF framework. Calculating, both numerically and algebraically, forms a core component of any mathematics classroom, but the main issue at hand is whether these passages can be attributed to one of the seven types of CDF, which depends strongly on the given circumstances. In some cases, calculations may form part of a passage of *EXPLAIN* if they are used to provide logical reasoning for a statement. Alternatively, calculations which simply lead the way to a solution may not fit into any of the seven CDF types, as shown in Example 6 below:

Example 6: Mathematical calculations in the CLIL mathematics classroom

> T: Ehm, so the next one is three (.) Ok, so we have four times three plus six times y is a hundred and twenty-six, and a hundred and fourteen divided by six equals (3) [Sf]?
> Sf: <un> xxx </un>
> T: I'm sorry?
> Sf: Nineteen.
> T: Nineteen (.) That's correct, I believe (.) Yes.

Example 6 shows a passage in which the teacher is guiding the class in substituting values for $x$ and $y$ into an equation with two variables and then determining the solution. In this case, the calculations do not form part of an overall CDF and consequently this passage is not coded as a CDF episode

A further important issue to be elucidated is the codification of instances of switching between different mathematical representations. Example 7 shown below presents such a situation:

Example 7: Switching between two mathematical representations

> T: Now, we have two **linear equations** (.) Both linear equations represent a linear=
> SX: =function.
> T: Function, and a **linear function** represents a **straight=**
> SX: **=line**.
> T: Line, correct.

Example 7 illustrates how a link is made between three different representations of a concept, namely an equation, function, and line. This passage clearly shows evidence of complex cognitive processes, and a detailed review of the seven types of CDF, as discussed in detail in section 4.3.2., indicates that the passage is best categorized as *DESCRIBE* as it refers to the graphic representation of the equation/function. Furthermore, the three different representations can be viewed as different possibilities of *describing* a single concept, and hence passages detailing different representations of a single concept are best coded as *DESCRIBE*.

An additional situation specific to mathematics classrooms which can be coded as *DESCRIBE* is the conversion of real-life context to mathematical language. This is illustrated in Example 8 shown below:

Example 8: *DESCRIBE* – translating an expression into the language of mathematics

> Sm: *y* decreased by thirty-five percent.
> T: Good, and in **math speak** or in **math write**?
> Sm: *y* times zero point six five

In Example 8 the task, taken from a German textbook, is first translated into English (the first utterance by Sm), and then converted into "math speak". Such passages can also categorized as instance of *DESCRIBE* as mathematical language is used to *describe* the given situation.

Finally, it is important to clarify differences between *DESCRIBE* and *EXPLAIN*, in particular with regard to the process description and EXPLAIN-HOW. These two aspects of the CDF types are very similar in nature and this may lead to difficulty in the coding process. The distinctive characteristic that differentiates episodes of EXPLAIN-HOW from the process description is that *EXPLAIN* includes some form of logical reasoning while *DESCRIBE* involves simply presenting a step-by-step set of instruction without providing the underlying logic to move from one step to the next. This is illustrated in the two passages presented in Example 9 below:

Example 9: *EXPLAIN* vs. *DESCRIBE*

a. T: So, **how do we find out if a pair is a solution** to an equation like this? What do we do?
   Sm: Put the numbers in.
   T: Exactly (.) We insert the figures.

b. T: Now, **how do we find the combinations**? We start *x* with the smallest natural number. What is the smallest natural number?
   SX: Null.
   T: Zero. Let's see if it works.

In Example 9, passage a. shows an episode of *EXPLAIN*, as in this case the statement is based on logical reasoning – if when the figures are inserted and you obtain a correct result, then the pair is a solution. In contrast, in passage b., the teacher simply begins a process description of how to find combinations (the episode continues for a longer period). There is not explicit reason given for starting *x* with the smallest natural number. Although this differentiation aims to provide some clarity to the distinction between

*EXPLAIN* and *DESCRIBE*, it must be noted that often in such contexts logical reasons may be implicit, and as such, a certain degree of ambiguity is unavoidable.

### 5.4.2. Modifications to the original framework

A significant adaption to the CDF construct as presented by Dalton-Puffer (2013) is proposed by Kross (2014) and adopted by Hopf and Hofmman (2015) as well as Brückl (2016), highlighting its overall relevance. Kröss (2014: 35) introduces a separate code to distinguish translations while allocating them to the overall CDF type *DEFINE*. This is of particular relevance in mathematics because, if mathematics is regarded as a further language in the linguistic space of CLIL classrooms, as discussed in greater detail in chapter 3., translations can link English vocabulary to already present mathematical concepts creating greater networks of meaning. Thus, in the data analysis, instances of translation will be coded with the label *DEFINE-TRANSLATION* and will be also be treated separately in the results.

As pointed out previously, the circumstances of CLIL mathematics classrooms create challenges for teachers to provide authentic material in the target language. Furthermore, it has been shown that the use of students' native language can benefit the learning process. In consequence, it is important to consider passages realized fully in German in the overall analysis. This modification of the framework was first introduced by Kröss (2014: 47) for the CDF types *DESCRIBE*, *EXPLAIN*, and *REPORT*. Brückl (2016: 47-48) elaborates on this idea and applies it to all CDF types, and her coding framework, as shown below in Table 9 will be adopted for this thesis:

| CDF type | CDF type exclusively or partially realized in English | CDF type realized exclusively in German |
|---|---|---|
| ***CLASSIFY*** | CL | CLG |
| ***DEFINE*** | DF | DFG |
| ***DESCRIBE*** | DS | DSG |
| ***EVALUATE*** | EV | EVG |
| ***EXPLAIN*** | EA | EAG |
| ***EXPLORE*** | EO | EO |
| ***REPORT*** | RE | REG |

**Table 9 Codes for English and German CDF types (Brückl 2016 adapted from Kröss 2014)**

As pointed out by Brückl (2016: 48), Table 9 does not include *DEFINE-TRANSLATION*, but as any translation always includes English language, it automatically fits into the first column as a CDF realized in English.

The final modification to the original framework used in this thesis was again first proposed by Kröss (2014), who, as mentioned previously in section 4.4., coins the term "moves" to describe realizations of a CDF type occurring in a broader episode of another CDF type. In the analysis of this thesis, the coding framework of Brückl (2016: 49) will be adopted, which uses the term "embedded CDF types" to describe such occurrences. Table 10 shows an overview of the codes for the main and embedded CDFs:

| CDF type | CDF codes | Embedded CDF code |
|---|---|---|
| ***CLASSIFY*** | CL | CLe |
| ***DEFINE*** | DF (DFt) | DFe (DFte) |
| ***DESCRIBE*** | DS | DSe |
| ***EVALUATE*** | EV | EVe |
| ***EXPLAIN*** | EA | EAe |
| ***EXPLORE*** | EO | EOe |
| ***REPORT*** | RE | REe |

**Table 10 Codes for main and embedded CDF types (Brückl 2016: 49)**

Table 10 illustrates that to code an embedded CDF the suffix -e is simply added to the original code, so for instance EVGe would be the code for an embedded German realization of *EVALUATE*. An example for the coding of embedded CDF types is given in Example 10 below, in which the teacher explains that a system of linear equations cannot have two solutions:

Example 10: Passage showing an embedded CDF

| | | |
|---|---|---|
| 01 | Two solutions cannot happen because two straight lines don't have= | EA **TS** |
| 02 | Sm: Two Schnittpunkte. | |
| 03 | T: Two points of= | DFte |
| 04 | Sm: =equations | **TS** |
| 05 | T: Intersection. So, two cannot happen, ok? | |

Example 10 shows an embedded realization of *DEFINE-TRANSLATION* in an episode of *EXPLAIN*. The translation can be categorized as embedded as it contributes to the overall communication of meaning intended in the episode of *EXPLAIN*.

### 5.4.3. The realizers

Section 4.4. highlighted some of the inconsistencies in findings of prior research in the distribution of CDFs across different realizers. In order to expand the amount of empirical evidence in this area as well as to provide insight into unique situation of the CLIL mathematics classroom, realizations of CDFs were also coded according to the realizer as shown in Table 11:

| Realizer | Code |
|---|---|
| **Teacher** | T |
| **Student** | S |
| **Teacher-Student** | TS |

**Table 11 Codes for realizers (Brückl 2016: 51)**

If a CDF was realised only by a teacher of by one or more students, then the passage was coded with T or S respectively. However, if the realization of the CDF occurred interactionally through teacher-student communication, then the passage was coded TS. For a brief period of time in L4, the class was visited by a native speaker assistant. All realizations of the native speaker assistant were also coded as T in order to simplify the data.

### 5.4.4. Overview of full coding scheme

In summary, all passages are coded according to the schemata described previously. This means that each realization can CDF can be categorized according to each of the following four variables:

1. CDF type: *CLASSIFY*, *DEFINE*, *DESCRIBE*, *EVALUATE*, *EXPLORE*, *EXPLAIN*, *EXPLORE*, *REPORT*.
2. Language of realization: German or English
3. Embeddedness: main CDF or embedded CDF
4. Realizer: teacher, student, or teacher-student.

These four characteristics allow CDFs to be assorted in a manner which allows the data to be accurately evaluated with regard to the five research questions. A full overview of all codes, as adapted from Brückl (2016: 53) is present in Table 12 over the next two pages:

| CDF TYPES | |
|---|---|
| **CL – CLASSIFY** | |
| CL | classification exclusively or partially in English |
| CLe | embedded classification |
| CLG | classification performed in German |
| CLGe | embedded classification performed in German |
| **DF – DEFINE** | |
| DF | definition exclusively or partially in English |
| DFe | embedded definition |
| DFG | definition performed in German |
| DFGe | embedded definition performed in German |
| DFt | translation |
| DFte | embedded translation |
| **DS – DESCRIBE** | |
| DS | description exclusively or partially in English |
| DSe | embedded description |
| DSG | description performed in German |
| DSGe | embedded description performed in German |
| **EV – EVALUATE** | |
| EV | evaluation exclusively or partially in English |
| EVe | embedded evaluation |
| EVG | evaluation performed in German |
| EVGe | embedded evaluation performed in German |
| **EA – EXPLAIN** | |
| EA | explanation exclusively or partially in English |
| EAe | embedded explanation |
| EAG | explanation performed in German |
| EAGe | embedded explanation performed in German |
| **EO – EXPLORE** | |
| EO | exploration exclusively or partially in English |
| EOe | embedded exploration |
| EOG | exploration performed in German |
| EOGe | embedded exploration performed in German |
| **RE – REPORT** | |
| RE | report exclusively or partially in English |
| REe | embedded report |
| REG | report performed in German |
| REGe | embedded report performed in German |

| REALIZERS | |
|---|---|
| T | teacher |
| S | student |
| TS | teacher-student |

**Table 12 Overview of all codes with explanations, adapted from Brückl (2016: 53)**

The extract presented below shows an interaction with numerous coded passages to illustrate the coding process. The overall episodes are indicated with the lines of the right side, while the embedded CDFs are shown through the shaded the grey areas. In general, the passage centres around linear equations in two variables:

Example 11: Fully coded CDF passage (L3)

| | | |
|---|---|---|
| 01 | T: So, linear equations, we already know what they are (.) What do you think of when I say that? | DFT **TS** |
| 02 | Sm1: <L1de> So lineare Gleichung. | |
| 03 | T: Lineare Gleichung </L1de> (.) And what do they look like? [Sm2]? | DS **TS** |
| 04 | Sm2: Straight line (.) | |
| 05 | T: Yes, visually they are a straight line, but an equation (.) What is that? Can you give me an example? | CLe **TS** |
| 06 | Sm2: *k* times *x* plus *d*. | |
| 07 | T: That's a function. <L1de> Lineare Gleichung, Herrschaften (.) Ein Beispiel für eine lineare Gleichung </L1de>, one example. | |
| 08 | Sm2: <L1de> F von, achso </L1de>. | CLe **TS** |
| 09 | T: No, that's a function. | |
| 10 | Sf1: Four *x* plus two *y* is (2) something. | |
| 11 | T: Is? | CLe **TS** |
| 12 | Sf1: Sixty? | |
| 13 | T: Whatever (.) Sixty. Fine, whatever (.) That's a linear equation, ok? So, you remember a linear equation can be turned into a linear function if we do what? | DS **TS** |
| 14 | Sm3: Turn the equation to *y*. | |
| 15 | T: That's correct, and the mathematical term is we solve the equation for *y* (.) So we solve the equation for *y* (.) How do we do that? [Sf2]? | |
| 16 | Sf2: Minus four *x*. | |
| 17 | T: That's good (.) And then? [Sm4]? | |
| 18 | Sm4: Divided by two. | |

# 6. Results and interpretation

The audio files of the seven lessons yielded a total of 326 recorded minutes with an average of 47 minutes per lessons. As mentioned previously in section 5.3., this is slightly less than the scheduled 50 minutes per class due to organisational factors, such as the teacher or students gathering their material and preparing for the lesson.

All results are presented in the charts and tables are given either in absolute or relative frequency. In charts, the relative frequencies are round to the nearest natural number (e.g. 7%) and in tables to one decimal place (e.g. 6.8%).

Finally, it should be noted that ordering of the findings of the data reflects the sequence of the five research questions of this thesis:

1. Which CDF types are realized in naturalistic mathematics classes?
2. What is the context in which the different CDF types are realized?
3. Who realises them?
4. How are the cognitive discourse functions interactionally realized?
5. Which language are CDFs realized in and how are different languages used to construct meaning?

## 6.1. Frequency and occurrence of CDF types

In total 486 CDF passages were coded which equates to an overall average of 69 CDFs per lesson, although it must be noted that there is a relatively uneven distribution as will be discussed later in this section. This means that approximately 1.4 CDFs are realized every minute, which aligns very closely with Dalton-Puffer's (2018: 15) figure of 1.5 CDFs per minute calculated from five different research projects. Table 13 below presents an overview of the overall occurrences of CDFs adding the results of this thesis in column 6 to those of these previous studies:

| **study/subject** | **1 physics** | **2 biology** | **3 econ** | **4 history** | **5 EFL** | **6 math** |
|---|---|---|---|---|---|---|
| **lessons** | 6 | 8 | 6 | 8 | 8 | 7 |
| **total CDFs** | 504 | 619 | 480 | 265 (SS only) | 481 | 486 |
| **CDFs/lesson** | 84 | 77 | 80 | 33 (SS only) | 60 | 69 |

**Table 13 Overall occurrence of CDFs across studies adapted from Dalton-Puffer (2018: 15)**

Table 13 illustrates that the results of this study shown in column 6 are consistent with findings of previous work, with the average number of CDFs realized per lesson located clearly within the intervals set by the other studies. This adds to the already considerable amount of empirical evidence indicating that CDFs do occur naturalistically in CLIL classrooms and also further validates the use of the construct as an appropriate tool for investigating classroom discourse in dual-lingual educational contexts.

With regard to the frequencies of the specific CDF types in this study, it is first useful to consider all occurrences of a certain type grouped together as shown in Figure 18:

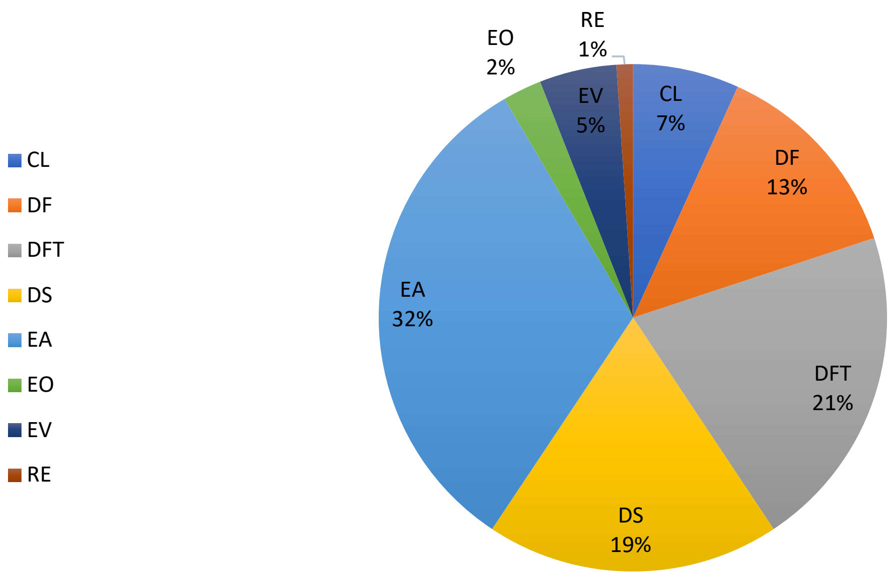



**Figure 18 Relative frequency of CDF types in percent**

Figure 18 presents an interesting overview, and it is immediately evident that there is no even distribution of the CDF types. Indeed, over 75% of all CDF realizations are categorized as one of the four types *EXPLAIN*, *DESCRIBE*, *DEFINE-TRANSLATION* and *DEFINE*. These results show some similarities to previous studies of CDFs in other subjects. Both Kröss (2011) and Hopf and Hoffmann (2015) found *DESCRIBE* to be the most frequently realized CDF type with 28% and 21% respectively, and in this study, *DESCRIBE* has a similar percentage, namely 19%, although it is not the most frequent CDF type. Furthermore, the high frequency of *DEFINE* and *DEFINE-TRANSLATION* aligns with Brückl's (2016) findings in which *DEFINE* constituted 26% of all CDF realizations (Brückl treat *DEFINE-TRANSLATION* as an individual CDF).

Four types of CDF, namely *CLASSIFY*, *EVALUATE*, *EXPLORE*, and *REPORT* are each realized less than 8% of the time, indicating that such realizations do not often occur in CLIL mathematics classes. The low frequency of *CLASSIFY* and *EVALUATE* corresponds with the research of both Brückl (2016) and Kröss (2011) in which both types have a percentage of less than 10%. However, there are also clear differences to the previous studies. Brückl (2016) finds a high frequency of *REPORT* in her data with 16%. Furthermore, Hopf and Hoffman (2015) identify a relatively even distribution of the CDF types which stands in stark contrast to the overview presented in Figure 18 above. This first impression of the data as well as the comparisons to previous studies clearly indicate that the unique circumstances of the

CLIL mathematics classroom require very specific cognitive processes with corresponding verbalisations, which will be discussed in closer detail in the next section.

Prior to a closer analysis of the CDF types in the mathematical context, it is important to consider the distribution of the CDF types across the seven lessons as presented in Table 14 below:

| | ***LESSONS*** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| ***CDF*** | ***L1*** | ***L2*** | ***L3*** | ***L4*** | ***L5*** | ***L6*** | ***L7*** | **TOTALS** |
| ***CL*** | 1 | 3 | 7 | 1 | 0 | 8 | 13 | **33** |
| ***DF*** | 14 | 8 | 10 | 4 | 6 | 15 | 7 | **64** |
| ***DFT*** | 11 | 17 | 11 | 6 | 20 | 30 | 6 | **101** |
| ***DS*** | 16 | 14 | 14 | 9 | 14 | 6 | 17 | **90** |
| ***EV*** | 0 | 1 | 0 | 3 | 3 | 14 | 3 | **24** |
| ***EA*** | 13 | 24 | 23 | 25 | 12 | 37 | 23 | **157** |
| ***EO*** | 2 | 7 | 0 | 0 | 1 | 2 | 0 | **12** |
| ***RE*** | 2 | 1 | 0 | 1 | 1 | 0 | 0 | **5** |
| ***TOTALS*** | **59** | **75** | **65** | **49** | **57** | **112** | **69** | **486** |

**Table 14 Absolute frequency of CDF types across lessons**

Overall, the total number of realizations per lesson range from around 50 to 75 except for L6, which forms an outlier with 112 realizations. When considering the frequencies of the individual CDFs in L6, it also becomes evident that this lesson also includes the highest number of five different types of CDF, namely CL, DF, DFT, EA, and EV. The causes for this spike in occurrences will be discussed in greater detail in the next section. L4 has the lowest total of CDF realizations with 49, but there are also two reasonable explanations for this outcome. Firstly, L3 and L4 were recorded as a double lesson towards the end of the school year (June 2019). At that point in time, all grades had been finalised, and in consequence, students were unfocused and at times disruptive causing the lesson to be less efficient and productive as would usually be expected. Secondly, during the course of L4, the teacher showed videos explaining a new mathematical procedure to students, and hence, there was less time overall dedicated to classroom interaction.

When regarding the individual CDF types, some are relatively evenly distributed across the seven lessons, for instance DF and DS, whereas others occur predominantly in single lessons. For instance, over 50% of all realizations of *EVALUATE* occur in L6. Additionally, over 80% of all instances of *CLASSIFY* are realized in either L3, L6, or L7. These results indicate that certain types of CDFs are required to greater or lesser extent depending on the overall context, determined by aspects such as subject matter or task type. Such phenomena are particularly relevant for the overall analysis because closer inspection of such tendencies can provide insight into how the different CDF types are realized in mathematics classrooms.

## 6.2. Qualitative analysis of CDF types

In order better understand the discursive space of CLIL mathematics classroom, it is important not only to investigate the frequency of the different CDF types but also to analyse the context in which the different types of CDFs are realized. This will allow for an explicit linking of CDF types with specific practices of CLIL mathematics classroom discourse, so the results of this study can inform future efforts to establish subject-specific curricula. Therefore, this section looks at the overarching characteristics and circumstances determining the distribution of the CDF types in the recordings in relation to research question 2: "What is the context in which the different CDF types are realized?".

### *CLASSIFY*

As indicated previously, *CLASSIFY* is a relatively rare CDF with only 33 overall realizations equating to 7%. The different varieties of *CLASSIFY* are outlined in Table 15 below:

| Code | Frequency | Percentage |
|---|---|---|
| CL | 24 | 72.7% |
| CLe | 8 | 24.2% |
| CLG | 1 | 3.0% |
| CLGe | 0 | 0% |

**Table 15 Frequencies of CLASSIFY codes**

The table indicates that *CLASSIFY* occurs mainly as a main CDF with only 8 occurrences embedded in a different CDF episode. Furthermore, English is overwhelmingly used to realize *CLASSIFY* with only a single realization being fully in German.

In the recordings, *CLASSIFY* is mainly used to assort a given example to an overarching class or group as shown in the passages below:

Example 11: Typical realizations of *CLASSIFY*

a. T: What is that? That's an equation (.) **What kind of equation is it?** Gentleman?
   Sm1: A function?
   T: No, it's not a function.
   Sm2: Function equation.
   T: It's a=
   Sm3: =it's a equation in two variables.
   T: It's an equation in two variables (.) That's correct.

b. T: *y* equals three times *x*, **what kind of function is that?** *y* equals three times *x*.
   [Sm]?
   Sm: Homogene.

T: Very good, a homogenous linear function

The two passages give examples of classification from general to specific – there is an example of an equation/function and it sorted into a specific class of each of the categories. In both cases the classification is introduced by the teacher using the questioning framework "What kind of ... is it/that?", and the teacher also acknowledges the answers of the students with the phrases "That's correct" and "Very good".

As mentioned in the previous section, *CLASSIFY* is realized predominantly in L3, L6, and L7, and the mathematical context of L6 will be described in greater detail to explain the higher use of the CDF type. The subject matter of L6 centred around closure of number sets, and discussing number sets always involves some form of discussion whether a specific number (for example $-4$) is element of a set or not. As was also the case in L6, the number sets are often shown in a Venn diagram presented in Figure 19 below:

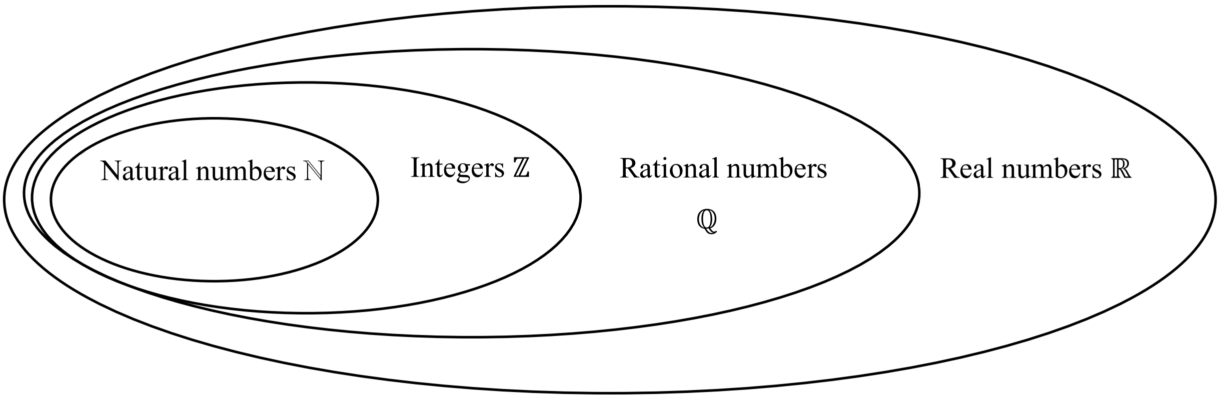



**Figure 19 Venn Diagram of number sets**

Figure 19 illustrates that in this context *CLASSIFY* is a very important function as students need to be able to determine which set a certain value belongs or doesn't belong to, as is the case in Example 12 below:

Example 12: *CLASSIFY* in the mathematical context

T: Every natural number is also a, what's the next larger if you want to say that? [Sm]?
Sm: Yeah, integer.
T: Integer (.) All of the integers include, no, the integers include all of the natural numbers, so we could say every natural number is an integer.

This passage even exemplifies a double classification. First the teacher and students classify all natural numbers as integers, and then the teacher also notes that the integers comprise all the natural numbers. This can also be framed according to Widdowson's (1979: 75) conceptualisation of the two directions of classifying as presented in section 4.3.2., shown in Figure 20:

| Every natural number | *is a member of*<br>*is placed in the class* | The integers |
|---|---|---|

| The integers | *Comprise* | The natural numbers |
|---|---|---|

**Figure 20 Two directions of classification for number sets adapted from Widdowson (1979: 75)**

Figure 20 shows that in this context, *CLASSIFY* takes on an important role, and that both directions of classification can be employed to characterize the relationships between number sets.

This description of *CLASSIFY* indicates that while it may not be the most frequent CDF type to occur in naturalistic CLIL mathematics classes, there are certain circumstances which require regular use of the function. Consequently, students could be introduced to certain sentences structures similar in nature to Widdowson's (1979: 75) framework presented above, so they are adequately equipped with the linguistic resources for expressing such relationships.

### *DEFINE*

Overall, *DEFINE* in itself is realized relatively often with 64 realizations equating to 13%. The exact distribution of the different codes is shown in Table 16 below:

| Code | Frequency | Percentage |
|---|---|---|
| DF | 12 | 18.8% |
| DFe | 31 | 48.4% |
| DFG | 8 | 12.5% |
| DFGe | 13 | 20.3% |

**Table 16 Frequencies of *DEFINE* codes**

Table 16 reveals that *DEFINE* is often embedded in a greater CDF episode. This means that the function is realized as a sub-component of another overarching CDF type. Furthermore, there is also a significant number of occurrences in German, amounting to approximately one third of all realizations.

In the mathematical context, *DEFINE* takes on a variety of different forms, and three of the most typical types will be illustrated in this section. Firstly, a great number of realizations of *DEFINE* can be framed through Trimble's (1985: 76) equation "T=C+D", as previously presented in section 4.3.2. This is illustrated through the following passage:

Example 13: Defining a term through class and difference

> Sm: <L1de> Homogene </L1de>.
> T: Very good, a homogenous linear function, meaning that it intersects with=
> S: =The <L1de> Nullpunkt </L1de>.
> T: Zero-zero, correct, ok, it intersects with the origin as we say.

From this passage, the definition of „homogenous linear function" can be described through the following equation:

$$homogenous\ linear\ function = linear\ function + intersects\ with\ the\ origin$$

Equations of this form allow definitions to be formulated precisely, and using this framework provides a high degree of clarity in communicating meaning, which is extremely important in mathematics. As also noted by Trimble (1985: 75-80), such definitions can also be further categorized according to the amount of information given, but such an analysis exceeds the scope of this thesis.

The second common form of *DEFINE* used in CLIL mathematics classes is the stipulative definition, which assigns a variable some form of meaning. As can be expected, such realizations are frequent in the recordings, especially due to the fact that fixed stipulative definitions are regularly repeated throughout the learning process. An example of an instance of *DEFINE* is shown below:

Example 14: Stipulative definition of the variable *d*

> T: When we say <L1de> *k-x* plus *d* <L1de>, what is the *d*? Can you find the word for me? [Sm]?
> Sm: Intercept.

In this passage the variable *d* is assigned meaning in the context of the general form of a linear function $y = k * x + d$.

Finally, the third relevant type of *DEFINE* is the operational definition, which, as outlined in section 4.3.2., Copi, Cohen, and McMahon describe as explaining a term by "tying the *definiendum* to some clearly describable set of actions and operations" (2011: 93). An example of an operational definition is shown below:

Example 15: Operational definition of the gradient

> T: <L1de> *x* Richtung. <L1de> and if you **divide delta *y* by delta *x*, so rise by run,** then you get the=
> Sm: <L1de> =Steigung. <L1de>
> T: And that in English is=?
> Sm: =Gradient.
> T: Gradient (.) That's correct

In the passage the gradient is clearly linked to the mathematical operation of dividing the rise and run of a linear function, and hence this can be categorized as an operational definition.

In conclusion, this section has presented the three main types of *DEFINE* realized in CLIL mathematics classes, and certain aspects of this analysis can certainly be used to inform future teaching. For instance, teachers could introduce students to the general equation „T=C+D" and use it in class to provide greater clarity for definitions, and also to have students deconstruct the linguistic components of a definition. Furthermore, the importance of stipulative definitions cannot be understated as it is critical for students to understand the definition of variables in any given context in order to be able to interpret expressions accurately, so teacher should ensure they repeatedly use both the target and native language to infuse variables with meaning.

*DEFINE-TRANSLATION*

*DEFINE-TRANSLATION* forms one of the most frequent CDF types, and this aligns with previously mentioned findings of Wilhelmer (2008: 106) who concluded that use of the L1 aids the construction of meaning in CLIL mathematics classroom. In total, *DEFINE-TRANSLATION* was realized a total of 101 times in all lessons which equates to 21% of all CDF realizations. The overall distribution of the codes is shown in Table 17 below:

| Code | Frequency | Percentage |
|---|---|---|
| DFT | 38 | 37.6% |
| DFTe | 63 | 62.4% |

**Table 17 Frequencies of *DEFINE-TRANSLATION* codes**

Table 17 indicates that *DEFINE-TRANSLATION* often occurs embedded in other CDF episodes. This follows logically when viewing segments of the data, as in such instances only single words are translated from one language to the other in order to facilitate the construction of meaning. An example of such a passage is given in the previous section in Example 15.

As established in the previous section, the whole episode of Example 15 can be classed as a stipulative definition, but within the passage there is a realization of *DEFINE-TRANSLATION*. In this case, the student first thinks of the German word for the concept, and the teacher then elicits the English translation for the word. Such occurrences of *DEFINE-TRANSLATION* are very frequent throughout the recordings and can also be analysed from the perspective of the CLIL mathematics classroom as a trilingual discursive space, as discussed previously in chapter 3., although this will be done in greater detail in response to the final research question.

The data also includes longer instances of *DEFINE-TRANSLATION*, which often occur as a result of the fact that there is no English schoolbook available which fully covers the Austrian curriculum and prepares for the Austrian Matura. Consequently, all tasks in the schoolbook used in the class are in

German. In L6, the focus of the class is to find and interpret mathematical expressions in real-life contexts. The teacher turns the German tasks into a CLIL activity by having students first translate the prompt into English and only then finding/interpreting the mathematical expression, which also explains the higher number of realizations of *DEFINE-TRANSLATION* in L6 in comparison to the other lessons. The introduction to such an activity is shown in Example 16 below:

Example 16: Translation of a task from the textbook into English

T: A hundred and sixty (4) now this is obviously in German (.) **We'll translate it first**.

In the age of Communicate Language Teaching (CLT) simple translation tasks are now viewed as obsolete in conventional language classes. However, in the given context of CLIL in mathematics, such activities certainly contribute to the learning process. Firstly, from the linguistic perspective, translation provides students with opportunities to practice vocabulary and create links between their native language and the L2. Secondly, and more importantly in the given circumstances, translation requires complete comprehension of the prompt of the task, and consequently, students engage in a form of "close reading". This offers an opportunity for a deeper understanding, so students develop their ability to understand a given situation and then describe it mathematically.

As outlined in this section, *DEFINE-TRANSLATION* is an important function in CLIL mathematics classroom as it is constantly used to create links between the two languages and the mathematical concepts. Furthermore, it can be said that, in general, this CDF type occurs in two main forms, namely either a single word or otherwise a longer passage of text or speech is translated from one language to the other.

### *DESCRIBE*

*DESCRIBE* joins *DEFINE-TRANSLATION* as one of the three most frequent CDF types with a total of 91 occurrences across the seven lessons equating to 19% of all realizations. A full overview of all codes is given in Table 18 below:

| Code | Frequency | Percentage |
|---|---|---|
| DS | 63 | 70.0% |
| DSe | 8 | 8.9% |
| DSG | 17 | 18.9% |
| DSGe | 2 | 2.2% |

**Table 18 Frequencies of *DESCRIBE* codes**

Table 18 shows that *DESCRIBE* is mostly realized in English or in a combination of German and English. Furthermore, it is evident that the CDF type is predominantly (almost 90% of the time) realized as an episode and not embedded within another function. Closer analysis of the data reveals that there are four main forms to the realization of *DESCRIBE* in the CLIL mathematics classroom.

In the mathematical context, students are often required to characterize diagrams and graphs, and such situations can be viewed as exemplary instances of *DESCRIBE*. In Example 17 shown below, the teacher asks the students to describe the gradient of two graphs of linear functions given on a worksheet:

Example 17: *DESCRIBE* used to characterize two graphs of linear functions

> T: The one on the left (.) You have two graphs, ok (.) The one on the left has what kind of gradient?
> Sm1: **Negative**.
> Sm2: **Positive**.
> T: **A positive gradient** (.) And the one on the right has a=
> SS: =**Negative.**
> T: **Negative gradient**.

Example 17 also illustrates that such passages of *DESCRIBE* also provide students with opportunities to use and practice vocabulary with specific meaning in the mathematical context, in this case negative, positive, and gradient.

A further important form of *DESCRIBE* in CLIL mathematics classes is using mathematics to describe real-life contexts, as also detailed in section 5.4.1.. Numerous examples of this type of *DESCRIBE* in interaction with *DEFINE-TRANSLATION* are given in L6 in which tasks were first translated into English and then described mathematically. Example 18 presents such a passage:

Example 18: A task is first translated to English and the described mathematically

> T: Good, now, [Sm].
> Sm: Ehm (.) there are two people.
> T: Ok.
> Sm: One person is *a* years old.
> T: Correct.
> Sm: And the other person is *b* years old.
> T: That's correct.
> Sm: And *b* is older than *a*.
> T: That's wonderful, and **now we need to express what using math**?
> Sm: Ehm, **the difference between their ages**.
> T: Good, the age difference, which is? If *b* is older than *a*?
> Sm: ***b* minus *a***.

The process is clearly shown in this passage in Example 18 in which the students first describes the situation in English (this is coded as *DEFINE-TRANSLATION*), and then the student uses mathematics to express the difference between the ages (this is coded as *DESCRIBE*). This interaction also further emphasizes the strong interrelationship between language and mathematics in CLIL classes.

As also explained in section 5.4.1., *DESCRIBE* codes for passages in which switches between mathematical representations occur, as presented in Example 19:

Example 19: *DESCRIBE* used to switch between mathematical representations

> T: So, this you remember (.) We said this (.) **Two equations symbolize two (.) straight=**
> Sm: =**lines**.

Example 19 clearly shows evidence of complex cognitive thinking processes as a link is made between two different mathematical representations using the verb "symbolize". While this form of *DESCRIBE* does not involve any elaborate linguistic structures, it is a critical component of mathematics teaching as students are required to comprehend different representations of a concept, such as formula, graphs, equations, or tables.

The final important form of *DESCRIBE* present in the data is the process description, as previously outlined in section 4.3.2, which Trimble (1985: 72) equates to "a series of instructions". This means that process descriptions can be used to refer to any passage in which a step-by-step guide is presented, as shown in Example 20 below:

Example 20: Process description of how to change a linear equation to a linear function

> T: How do you change this [linear equation] into a linear function?
> SX: Minus *a* times *x*.
> T: [...] Now, and **then**?
> SX: Divided by *b*.
> T: And then divided by *b*, good

Example 20 shows an interaction in which the teacher and student interactionally describe the process for turning a linear equation into a linear function. This is only a short process description, but the sequence nevertheless includes one of the linguistic markers introduced in section 4.3.2., namely "then" (Gillett, Hammond & Martala 2009: 123). Furthermore, while this passage is relatively inexplicit and unstructured, it can be assumed that process descriptions will be much more organized when presented in written form. Consequently, such forms of *DESCRIBE* provide opportunities for CLIL teachers to explicitly teach and have students actively use some of the linkers outlined by Gillet, Hammond, and Martala (2009: 123), for instance "Firstly", "Subsequently", and "Finally".

In conclusion, it can be said the in CLIL mathematics classes *DESCRIBE* is predominantly realized in one of the four following variations:

1. Describing graphs or diagrams using specific mathematical language
2. Describing a given context through the language of mathematics
3. Describing a concept by switching representations
4. Describing a process through a set of instructions

These situations also all provide opportunities for language focus, and investigating in detail the specific linguistic requirements of the different types of *DESCRIBE* can provide a platform for a greater understanding of the interrelationship of content and language in CLIL mathematics classes.

*EVALUATE*

The CDF type *EVALUATE* exhibits a total of 24 realizations across the seven lessons, and it should also be noted that 14 occurrences take place in L6. This equates to 5% of all CDF realizations, making *EVALUATE* a rare CDF type in CLIL mathematics classes, and there are even two lessons, L1 and L3, in which it does not occur at all. A complete overview of all *EVALUATE* codes is presented below in Table 19:

| Code | Frequency | Percentage |
|---|---|---|
| EV | 14 | 58.3% |
| EVe | 3 | 12.5% |
| EVG | 7 | 29.2% |
| EVGe | 0 | 0% |

**Table 19 Frequencies of *EVALUATE* codes**

Table 19 illustrates that *EVALUATE* is realized mainly as an individual episode rather than embedded in other CDF types. Furthermore, the table also shows that it is realized both in the target language as well as solely in German, although the former outweighs the latter.

In analysing realizations of *EVALUATE* in the data, it is first important to point out that the low frequency does not reflect a lack of feedback given from the teacher to the students. Indeed, the teacher gave feedback through a variety of phrases as shown in Example 21 below:

Example 21: Corrective feedback by the teacher

a. T: **Good** (10) ok.
b. T: Negative gradient, **correct**.
c. T: **That is beautiful, correct**.

While all segments presented in Example 21 give some form of feedback to students, none were coded as *EVALUATE*. This is due to the fact that, as previously explain in section 4.3.2., evaluation as understood as a type of CDF requires "evidence, criteria, standards or reasons which support the evaluation that is being made" (Dalton-Puffer 2015: 42). This explains the low count of *EVALUATE* despite a continuous cycle of feedback in the interactions between teacher and students.

A further interesting characteristic of *EVALUATE* in the recordings is the high frequency in L6, which indeed constitutes over 50% of all realizations. This can be attributed to a certain question type, which also occurs in the mathematics Matura, being practiced in class. This task involved determining whether a certain statement was true or false, i.e. evaluating whether it was correct or incorrect. All these passages also included a clear explanation for the evaluation and as a result were coded as *EVALUATE*. One of these passages is presented in Example 22 below:

Example 22: Task involving evaluation of a statement

> T: Real number (.) So, [Sf], **every repeating decimal is irrational**.
> Sf: **No.**
> T: **No (.) Because** every repeating decimal is=
> Sf: =rational.
> T: Rational (.) <L1de> Jede periodische Dezimalzahl kann ich als=
> Sm: =Bruch darstellen.
> T: Bruch darstellen und alles was ich als Bruch darstellen kann ist=
> SS: =rational </L1de>.

In Example 22 the statement to be evaluated is "every repeating decimal is irrational", which the student identifies as false. As an explanation is given for the evaluation, this passage can be classed as a realization of *EVALUATE*.

In conclusion, EVALUATE is only rarely realized in CLIL mathematics classrooms, although it must be emphasized that there is continuous feedback provided on student answers. This can be attributed to the fact that as a hard science, mathematical knowledge is constructed almost entirely through logical deduction, and as such, subjective evaluations are mostly irrelevant. Nevertheless, when opportunities for evaluation arise, teachers can provide students with scaffolding to provide the linguistic means for expressing them.

*EXPLAIN*

Due to the logical formation of the mathematical body of knowledge, it was to be expected that *EXPLAIN* would be a very important CDF type in CLIL mathematics classes, and this assumption is confirmed in the results. *EXPLAIN* is indeed the most frequently realized CDF type with a total of 157 occurrences equating to 32% of all CDFs. This means that almost every third passage identified as a function was coded as *EXPLAIN*. A full overview of all codes is presented in Table 20:

| Code | Frequency | Percentage |
|---|---|---|
| EA | 74 | 47.1% |
| EAe | 41 | 26.1% |
| EAG | 18 | 11.5% |
| EAGe | 24 | 15.3% |

**Table 20 Frequencies of *EXPLAIN* codes**

Table 20 shows that although *EXPLAIN* was often realized as an episode, it was also embedded in another CDF type over 40% of the time. This is due to the fact that *EXPLAIN* in its embedded form provides a reason or cause for what is communicated in the overarching function, as illustrated in

Example 22 above, in which *EXPLAIN* is embedded in the overall evaluation of a statement. Table 20 also indicates that the function is also often realized solely in German, which again emphasizes that explanations in students' native language are helpful to the overall negotiation of meaning.

In order to provide into the use of *EXPLAIN* in the recordings, it is first useful to review the definition of the OED as presented by Dalton-Puffer (2015: 44):

> *Explain 3*: To make clear the cause, origin, or reason of.

The quintessential aspect of the definition is that *EXPLAIN* requires some form of logical reasoning linking one step to the next. This is also what differentiates *EXPLAIN* from *DESCRIBE*, as in an explanation, there must be a reason or cause given for a course of action rather than in a process description, which simply lists the steps to be completed. Example 23 shows a passage of *EXPLAIN* from the data:

Example 23: Episode of *EXPLAIN*

> T: <L1de> Gut </L1de>, in 4a they ask us write the equation of a straight line that is parallel to y equals three *x* plus three, in 4a (.) Can you give the equation of any straight line that is parallel to this one? [Sf]?
> Sf: Three *x* plus four.
> T: Correct, yeah (.) Three *x* plus four is parallel **because** it has the same=
> Sm: =*k*.
> T: Or in English?
> SS: Gradient.
> T: Gradient.

In the passage shown above in Example 23 the student gives a correct answer, and the teacher then elicits the reason using the key word "because". Explanations are also often initiated through use of the question "Why?". This is underlined in the data with "because" occurring a total of 87 and "why" a total of 46 times across the seven lessons. There are naturally a number of other words and phrases used in realizations of *EXPLAIN*, but the underlying common factor is that all of them express causality.

As discussed previously in section 4.3.2., *EXPLAIN* can also be conceptualized as a chain of reasoning, in which one logical assumption leads to the next, as presented in Example 24 below, in which the class is formulating a rule for determining whether a number is divisible by six:

Example 24: Chain of reasoning in an explanation

> T: Now, the rule is if a number is divisible by six, then it needs to be an even number, <L1de> eine=
> Sm1: =gerade Zahl.
> T: Gerade Zahl </L1de>, and it needs to be divisible by?
> SS: Six.
> T: Not six, but by=

Sm2: =Three.
T: Three, and when are numbers divisible by three? You just said that (.) If you take the sum of the figures, and you can divide it by=
SX: =three.
T: Three (.) Then it's divisible by=
Sm3: Six.
T: No, then it's divisible by=
SX: Three.
T: Three, and then if it's an even number as well [...] Now, so **if a figure is divisible by two and by three, it is also divisible by=**
SX: **=six.**

In this passage the teacher determines that a number is divisible by six if it is divisible by both two and three and also elaborates on the criteria for these rules. The individual steps in a chain of reasoning can also be illustrated graphically as shown in Figure 21 below:

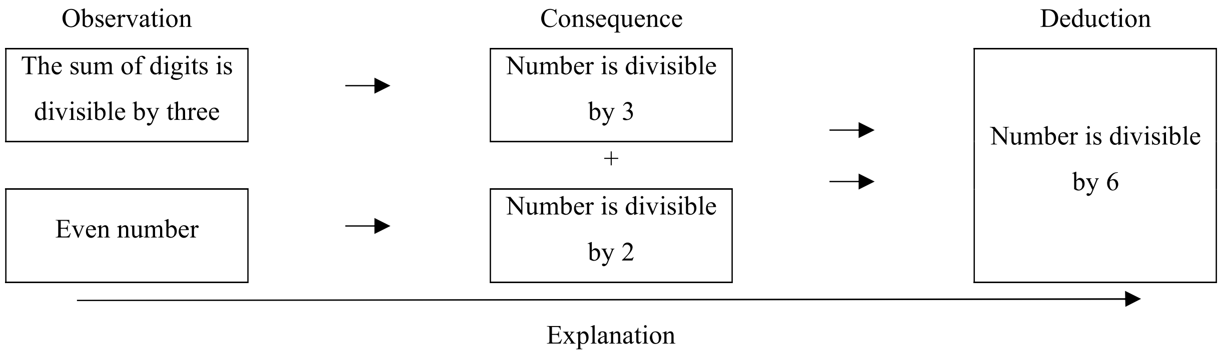



**Figure 21** ***Cause and effect*** **adapted from Hopf and Hofmann (2015: 49) from Widdowson (1979b: 108)**

Figure 21 illustrates the logical deduction involved in arriving at the final conclusion, and such chains of reasoning are very common in mathematics teaching.

In conclusion, it be noted that *EXPLAIN* is one the most important CDF types in CLIL mathematics teaching, and this section has illustrated the clear logical deduction involved in realizing the function. Additionally, it has also be indicated that certain words and phrases are essential in formulating explanations, and  further linguistic analysis of *EXPLAIN* may lead to the identification of concrete linguistic structures that can be introduced explicitly in the CLIL classroom, so students are equipped with the necessary language capacities for realizing *EXPLAIN* episodes.

*EXPLORE*

Although section 4.3.2. outlined the potential of *EXPLORE* in the mathematics classroom, the recordings showed only 12 realizations in total in all seven lessons equating to approximately 2% of all CDFs. An overview of all codes is given in Table 21 below:

| Code | Frequency | Percentage |
|---|---|---|
| EO | 9 | 75% |
| EOe | 2 | 16.7% |
| EOG | 1 | 8.3% |
| EOGe | 0 | 0% |

**Table 21 Frequencies of EXPLAIN codes**

Table 21 indicates that *EXPLORE* was predominantly realized as an episode rather and embedded in a different CDF type. Furthermore, it was mainly realized in a combination of English and German with only a single passage being coded as EOG.

As established previously, mathematics as a subject is characterized by a high degree of clarity. In consequence, students are overwhelmingly required to provide answers based on logical reasoning rather than speculating about possible results, and although, as discussed in section 4.3.2., inviting students to make predictions about possible outcomes has its advantages, whether this occurs or not is strongly dependent on a teacher's individual style of teaching. However, despite the low frequency of the CDF type in the data, analysing realizations of *EXPLORE* may provide some insight into how the function is realized in the CLIL mathematics classroom. A passage showing an instance of *EXPLORE* is shown in Example 25 below:

Example 25: Episode of *EXPLORE*

> T: Now, if we look at the graph and the pictures that we see here, ehm, **what do you think the word gradient means**? Look at the material, what could the word gradient be (3) Gradient (.) Yes.
> Sm1: <L1de> Graph </L1de>.
> T: No (.) That would be a graph (.) Have a look, read a bit (.) You don't need to read much to find out what it could mean. [Sm2]?
> Sm2: <L1de> Steigung </L1de>.
> T: <L1de> Die Steigung, genau </L1de> (.) Gradient <L1de> ist die Steigung </L1de> (.) What we would in German would we call a *k*, <L1de> Steigung </L1de>

In this segment, the teacher encourages the students to have an informed guess of what the word "gradient" means based on the information given on the worksheet. This is an interesting example as in this case the students are asked to infer the meaning of the word "gradient", which they already know the German term for, based on mathematical knowledge they are already familiar with. In this sense, it can be said that the passage involves a form of linguistic exploration.

Realizations of *EXPLORE* in this study are limited, and therefore a more detailed analysis is not feasible. However, the thesis has previously discussed the advantages of introducing mathematical explorations into teaching, and in this context, students can also easily be introduced to relevant items of vocabulary, for instance "assume", "predict", or "imagine" (Dalton-Puffer 2007: 160). This would firstly bring greater diversity to the CLIL mathematics classroom and also provide ample opportunities for language use.

*REPORT*

Overall, *REPORT* is the least frequent CDF type, being realized a total of only 5 times. This accounts for only 1% of all CDF occurrences. A full overview of all *REPORT* codes is shown in Table 22 below:

| Code | Frequency | Percentage |
|---|---|---|
| RE | 5 | 100% |
| REe | 0 | 0% |
| REG | 0 | 0% |
| REGe | 0 | 0% |

**Table 22 Frequencies of *REPORT* codes**

Table 22 shows that *REPORT* was realized only as an episode and always at least partially in English. Due to the very few realizations in the data, it is impossible to make any precise observations on this CDF type. However, two passages will be briefly described as they are instances which may give some insight into how *REPORT* is realized in CLIL mathematics classes. The first is presented in Example 26 below:

Example 26: Episode of *REPORT*

T: That's ok, **so what did you do?** You had a *y* intercept of five. Can you show me that?
Sf: <un> xxx </un>
T: Excellent. And a gradient of=
Sf: =three.
T: Three. Can you show how you did that, just so I.
Sf: I went one to the right side.
T: One to the right (.) Good.
Sf: And three.
T: Excellent. Ok. Thank you

Prior to the interaction presented above, the student completed a task on the board, and then the teacher asks the student to recount what she did: "so what did you do?". In this case, the teacher helps the students throughout the interaction, but such instances provide opportunities for students to use language to present their actions. In particular, such types of reporting could provide an opportunity for teachers to explicitly review and then have students practice the past simple tense.

Example 27 below shows a second passage of *REPORT*. This interaction takes place in L4, in which the teacher showed students a YouTube video in English explaining a certain mathematical procedure:

Example 27: Reporting on video

> T: So you see what he did there? This is already solved for *y*, ok? This one looked a bit weird, but the only thing he needed to do was=
> SX: =divide by three.
> T: Divide by three, and then you have *y* equals, just as one, ok?

This passage is similar to Example 26 above in that the teacher recalls and summarizes the speaker's actions from the video. Again, linguistically reporting in such a manner makes use of the past tense, which could be explicitly factored into the teaching sequence. Furthermore, this segment is of particular relevance because it uses authentic English material to introduce a concept. Such videos could also be used as a form of comprehension activity with students learning content but also indirectly practising their comprehension skills. Naturally, such sequences can also be elaborated, for instance by preparing pre-comprehension worksheets, but it must be said that this would be extremely time-consuming for teachers to do on a regular basis.

In conclusion, *REPORT* formed only a minimal part of all CDF realizations, but it may occur more frequently when investigating a larger sample of lessons. Furthermore, the passages of *REPORT* presented from the recordings describe the specific circumstances in CLIL mathematics classes under which the CDF type occurs naturalistically. Finally, as is the case with all other CDF types, reporting provides opportunities for pragmatic language use, and greater understanding of this CDF type will allow for a formulation of explicit language aims when realizing *REPORT*.

### Overview of CDF types

The analysis of the context in which the different CDF types occur indicates that there are specific circumstances in CLIL mathematics classroom which encourage the realization of certain CDF types. An overview of the main discursive practices of the individual CDF types in the recordings is presented in Table 23 on the following page:

| CDF types | Realizations in data |
|---|---|
| *CLASSIFY* | • In response to the question "What kind of ... is ...." <br> • Determining whether a number or numbers are elements of a set |
| *DEFINE* | • Definitions of the form "T=C+D" <br> • Stipulative definition: assigning meaning to a variable <br> • Operational definition: linking a certain term to a certain set of actions/calculations |
| *DEFINE-TRANSLATION* | • Translating individual words <br> • Translating longer tasks from the German schoolbook into English |
| *DESCRIBE* | • Descriptions of graphic representations, such as graphs or diagrams <br> • Descriptions of a given context through the language of mathematics <br> • Descriptions of a certain concept or idea by switching representations <br> • Process descriptions: describing a process through a set of instructions |
| *EVALUATE* | • Evaluation of whether a given statement is true or not with an appropriate explanation |
| *EXPLAIN* | • Clarification of misunderstandings <br> • Explanations through logical deduction and reasoning |
| *EXPLORE* | • Mathematical explorations in which students predict outcomes or solutions <br> • Explorations in which students guess the meaning of a word |
| *REPORT* | • Report of approach to a task <br> • Report of what was presented in a video |

**Table 23 Overview of contextual circumstances of CDF types**

Table 23 provides some insight into the relationship between language and content in CLIL mathematics classrooms, but it must also be emphasized that this is a preliminary list based on a very small collection of recordings of classes taught by one single teacher. Evidently, much more empirical work is required to confirm any of these findings and create a detailed framework describing CDF realizations in the mathematical context.

## 6.3. Realizers of CDFs

Research question 3 addresses the issue of who realizes CDFs, and in order to provide insight into this area, this section will first present an overview of the overall distribution, which will be compared to the findings of other research projects. This will be followed by a qualitative analysis of passages from the recordings to investigate the underlying causes for the results of the data.

In addition to being categorized by CDF type, every CDF passage was coded according to the realizer with the following codes:

1. S – realized solely by students
2. T – realized solely by teacher
3. TS – realized by teacher and students interactionally

Figure 22 below shows the overall distribution of the codes:

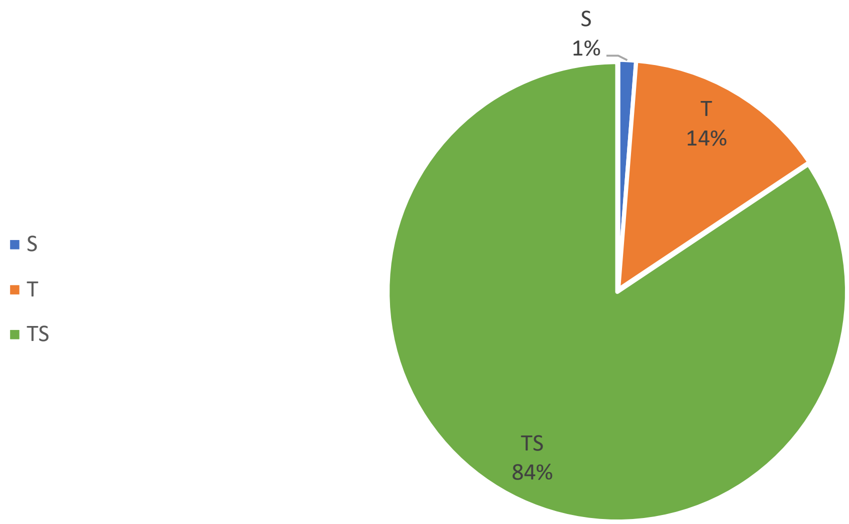



**Figure 22 Distribution of realizers as percentages**

Figure 22 provides an interesting depiction of the data with CDFs overwhelmingly being realized by students and teachers interactionally accounting for 84% of all realizations. The remaining CDFs are almost all realized by the teacher in isolation with student realizations accounting for only 1%, The results shown above bear some resemblance to findings of previous research , but no clear pattern can be determined, which is also due to the fact that prior studies have also produced differing results. Kröss' (2011) analysis of CLIL biology classes also found TS to be the most common realizer with 59%, but in Hopf and Hofmann (2015), who investigated CLIL physics lessons, established the main realizer to be the teacher accounting for 67% of all realizations. Brückl's (2016) work produced somewhat similar results to Hopf and Hofmann (2015) with the teacher being to most dominant realizer with 45%, and TS realizations accounting for only 18%. These varying results indicate that there is no common trend in the distribution of realizers, and the differences could be the caused by a variety of factors, such as the subject in question as well as individual teaching styles.

The overall impression given by this data is that in the CLIL mathematics classroom, there is a great amount of interaction between the teacher and the students with the teacher also at times elaborating on the discussion or providing further details or information on a certain topic. Furthermore, it can be said that in general, situations in which students realize CDFs completely of their own accord are extremely rare. These general assumptions are further confirmed when analysing the recordings qualitatively. Example 28 present a typical passage taken from the recordings:

Example 28: Typical passage of teacher-student interaction

> T: What is a straight line, [Sm1]?
> Sm1: <L1de> Gerade <L1de>.
> T: <L1de> Eine Gerade <L1de> (.) A straight line is <L1de> eine Gerade, genau <L1de> (.) Ehm, ok (.) The one on the left (.) You have two graphs, ok (.) The one on the left has what kind of gradient?
> Sm2: Negative.
> Sm3: Positive.
> T: A positive gradient (.) And the one on the right has a=
> SS: =Negative.
> T: Negative gradient,

Example 28 above shows two different CDF episodes. The first one is an instance of *DEFINE-TRANSLATION*, in which the "straight line" is translated to German. The second part of the passage is coded as *DESCRIBE*, as the teacher and students describe the graphs of two straight lines. Both of these CDF passages are coded as TS, and they are exemplary for the general flow of the lessons. The teacher acts as a guide through the material providing a structure and direction for the interaction. However, the teacher also integrates students' prior knowledge into the discourse by using question to elicit answers. In the first CDF episode, he addresses a student directly for the translation of "straight line", and in the second, he asks students to identify the gradient of the graphs.

This form of fluid interaction has two main advantages for the classroom. Firstly, it keeps the students constantly involved in the learning process by having them take part in the construction of knowledge. Secondly, the teacher receives immediate feedback on possible student misunderstandings and can correct these if necessary. This form of mathematics teaching, initiation-response-evaluation (IRE), is established by Franke, Kazemi, and Battey (2007: 229) to be the predominant style of teaching approach found in mathematics classrooms. Consequently, it can be presumed that the findings of this study are somewhat representative of a typical CLIL mathematics classroom, although more research is required to form a more concrete picture.

In response to research question three, it can be said that in the CLIL mathematics classroom, CDFs are predominantly realized through teacher and student interaction, whereby the teacher takes on a guiding role, eliciting answers from the students and integrating them in the learning process. For teachers, this means it is important to take into consideration students' prior knowledge both content-wise and linguistically, so they can prepare the appropriate questions to elicit information successfully. Furthermore, it should also be noted that the degree of student involvement will vary from class to class, and in consequence, it is important for teachers to adapt their level of contribution accordingly. Finally, future research should also investigate which CDF types are mainly realized by students and teachers in isolation, as, due to the low frequency of such CDFs in the data of this thesis, this area will not be analysed in any greater detail.

## 6.4. Interactional realization of different CDF types

An important area of research both in the context of this thesis but also in relation to an overall validation of the CDF construct is the interactional realization the different CDF types, as outlined in research question four. As described in detail in section 4.3.1., there are no clear limitations to each CDF type, meaning that there are overlapping areas between them. Furthermore, as discussed in section 4.4., the concept of embedded CDFs was adopted from Brückl (2016) in order to describe CDF types occurring in overarching CDF episodes. This section aims to provide insight into the relations between different CDF types by first looking at the distribution of CDF episodes and embedded CDFs, and then qualitatively analysing certain passages.

Table 24 shows the overall distribution of CDF episodes and embedded CDFs:

| Embedded CDF/CDF episode | Total | Percentage |
|---|---|---|
| CDF episodes | 291 | 59.9% |
| Embedded CDFs | 195 | 40.1% |

**Table 24 Overview of CDF episodes/embedded CDFs distribution**

Table 24 shows that CDFs mostly occur as individual episodes, but there is also a high percentage of embedded CDFs, meaning that CDF types are regularly realized as part of a different overarching CDF. The next interesting issues then are which of the different CDF types are realized as embedded CDFs and also which overarching CDF episodes they occur in. Table 25 presents an overview matching the embedded CDFs shown in the vertical columns to their correspondent CDF episodes shown in the horizontal rows. It should be noted that the language of the CDFs was not considered in this analysis, so, as an example, CL and CLG were grouped together to CL as were CLe and CLGe to CLe:

| | Embedded CDFs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **CDF Type** | **CLe** | **DFe** | **DFTe** | **DSe** | **EVe** | **EAe** | **EOe** | **REe** | **Totals** |
| **CL** | 0 | 3 | 2 | 0 | 0 | 7 | 0 | 0 | **12** |
| **DF** | 0 | 1 | 10 | 0 | 0 | 4 | 0 | 0 | **15** |
| **DFT** | 0 | 5 | 8 | 0 | 0 | 1 | 0 | 0 | **14** |
| **DS** | 5 | 15 | 17 | 0 | 2 | 22 | 0 | 0 | **61** |
| **EV** | 1 | 0 | 6 | 0 | 0 | 19 | 0 | 0 | **25** |
| **EA** | 2 | 17 | 17 | 10 | 1 | 8 | 2 | 0 | **57** |
| **EO** | 0 | 3 | 2 | 0 | 0 | 4 | 0 | 0 | **9** |
| **RE** | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | **1** |
| **Totals** | **8** | **44** | **63** | **10** | **3** | **65** | **2** | **0** | |

**Table 25 Distribution of embedded CDFs across CDF episodes**

Table 25 shows that that CDF types such as *EXPLAIN* and *DEFINE-TRANSLATION* regularly occur in embedded form, whereas *EVALUATE*, *REPORT*, and *EXPLORE* are realized only very rarely embedded in another CDF episodes. Furthermore, it can also be noted that *EXPLAIN* and *DESCRIBE* also tend to include embedded CDFs in their realizations. However, in order to be able to analyse the results objectively, it is important relate the frequencies of CDF types in embedded forms in relation to their overall frequency as presented below in Table 26

| CDF types | Embbeded realizations | Total realizations | Percentage |
|---|---|---|---|
| ***CL*** | 8 | 33 | **24.2%** |
| ***DF*** | 44 | 64 | **68.8%** |
| ***DFT*** | 63 | 101 | **62.4%** |
| ***DS*** | 10 | 90 | **11.1%** |
| ***EV*** | 3 | 24 | **12.5%** |
| ***EA*** | 65 | 157 | **41.4%** |
| ***EO*** | 2 | 12 | **16.7%** |
| ***RE*** | 0 | 5 | **0%** |

**Table 26 The percentage frequency of embedded CDFs of overall frequency of CDF type**

Table 26 illustrates that in relative terms there are three CDF types that are notably realized in embedded form, namely *DEFINE*, *DEFINE-TRANSLATION*, and *EXPLAIN*, and these will be analysed in greater detail.

Reviewing Table 26 above, it can be observed that both *DEFINE* and *DEFINE-TRANSLATION* are predominantly embedded in the CDF types *DESCRIBE* and *EXPLAIN*. Indeed, in both cases over 50% of all embedded codes occur in *DESCRIBE* or *EXPLAIN* episodes. This can be explained by the fact that often phrases specific to the mathematical context are used to describe images or explain concepts. Consequently, it is necessary to define the required terms, either through an English definition or by translating to the native language. Example 29 below typifies such a situation:

Example 29: *DEFINE* and *DEFINE-TRANSLATION* in another CDF episode

> T: What is the solution for this kind of equation? (5) For this kind of equation, what's the solution?
> Sm1: *y*.
> T: *y*. And?
> Sm2: *x*.
> T: *x*. So it's not one number, but it's=
> SX: =Two.
> T: **Two, what do we call two things together?**
> SX: **A pair.**
> T: We call it a pair (.) Ok, so the solution is a **pair of numbers, <L1de> ein Wertepaar </L1de>**, and only if you put in both, then it works.

Example 29 presents a passage which is coded as *DESCRIBE* as it describes the type of solution given for a linear equation with two variables, namely a pair of numbers. Firstly, the teacher and student define the term for such solutions, namely "a pair", which is the embedded definition. Secondly, the term is then also translated into German, "pair of numbers, ein Wertepaar". Consequently, in this passage exhibits both embedded *DEFINE* and an embedded *DEFINE-TRANSLATION* within an episode of *DESCRIBE*. Example 29 is exemplary in the sense that it shows the importance of precise definitions in mathematics, and hence, *DEFINE* and *DEFINE-TRANSLATION* are commonly realized embedded in other CDF types.

Although not to the same degree as *DEFINE* and *DEFINE-TRANSLATION*, the CDF type *EXPLAIN* also frequently occurs in embedded form. Furthermore, as can be seen in Table 25, *EXPLAIN* in embedded form is predominantly realized *EVALUATE* and *DESCRIBE*, although it should be noted that it occurs in episodes of all other CDF types apart from *REPORT*. This can be attributed to the fact that explanations are often used to provide logical reasoning as shown below in Example 30:

Example 30: *EXPAIN* embedded in an episode of *CLASSIFY*

> T: And we call that a, **what kind of equation**? What do we say in German? What's the title of this topic? Yeah?
> SX: <L1de> Lineare </L1de>.

T: <L1de> Lineare Gleichung, genau </L1de> (.) A linear equation (.) Now **why do we call it a linear equation**? Why do we call it a linear equation? We know the word linear from somewhere else (.) Which other topic do we know? Yes.
Sm: **Because it's a line**.
T: Because it's a straight line (.) That's correct

Example 30 shows an episode of *CLASSIFY* introduced by the guiding question "what kind of equation?", which is a form of classification from general to specific. The teacher then seeks to build on students' prior knowledge by eliciting a logical explanation for why the term is "linear equation", namely because graphically it is represented through a straight line.

*EXPLAIN* has a high number of occurrences embedded in *EVALUATE* with a total of 19 out of 65 total embedded realizations. As previously described in section 6.2., this can be ascribed to a certain question type used in mathematics, which also occurs in the Austrian Matura, in which students are tasked with evaluating whether a certain statement is true or false, as shown in Example 31 below:

Example 31: *EXPLAIN* embedded in an episode of *EVALUATE*

T: Good (.) Then this here?
Sm: **False.**
T: **Are the natural numbers a subset of the negative real numbers?**
SS: No.
T: No **because** there is not a single natural number that is included in the negative real numbers, so that is definitely wrong

In this example, the statement that is evaluated is "The natural numbers are a subset of the negative real numbers". This is identified to be false and is then following by the embeded explanation, namely that "there is not a single natural number that is included in the negative real numbers". The structure of such tasks is the reason for the high number of occurences of *EXPLAIN* embedded in *EVALUATE*, despite the relative low frequency of *EVALUATE*. Overall it can be said that *EXPLAIN* regularly occurs in embedded form due to the logical nature of mathematics, which leads to the teachers regularly eliciting logical explanations for concepts and links in episodes of other CDF types.

The interrelationships of different CDF types is a complex matter, and much further detailed analysis would be required to form any clear links. However, the reults of the data indicate that CDFs are indeed often realized interactionally. Furthermore, certain tendencies can be identified, in particular that *DEFINE*, *DEFINE-TRANSLATION*, and *EXPLAIN* are most frequently realized in embedded form, which indicates the CDF type‘s importance in developing understanding in the subject of mathematics. These findings also conform with the results of previous studies. Brückl (2016) also determined *DEFINE-TRANSLATION* and *EXPLAIN* to be the two most frequent embedded CDFs with the latter also being among the most common in studies by both Hopf and Hofmann (2015) and Kröss (2011). In consequence, it can be observed that *EXPLAIN* is often realized in embedded form across a range of different subjects and that there are also differing trends in different subjects. In mathematics, for instance, *DEFINE* and *DEFINE-TRANSLATION* take on an important role in clarifying meaning, and subsequently they exhibit a high number of occurrences embedded in other CDFs.

## 6.5. Languages in CLIL mathematics classroom

The final area of interest for the research focus of this thesis is the use of the different languages to communicate meaning in the CLIL mathematics classroom. In this context, it is not only important to investigate the use of the target language, English, and students' native language, German, but also to consider the function of the language of mathematics, as previously described in the third chapter. In this regard, this section will first present a quantitative analysis of the language CDFs are realized in and then analyse the interwoven use of the different languages in passages from the recordings.

As discussed in section 5.4., CDFs were also categorized according to language, with an added "G" indicating a CDF realized in German, although it must be noted that to ensure consistency in coding, passages were only coded as German if realized exclusively in German. For example, a *CLASSIFY* episode realized in a combination of English and German would be coded as **CL**, while a *CLASSIFY* passage realized exclusively in German would be coded as **CLG**. Table 26 provides an overview of the number of passages realized in the different languages as well as frequency of the CDF type *DEFINE-TRANSLATION*, which takes on a linking function between German and English:

| **Language of realization/ CDF type** | **Total** | **Percentage** |
|---|---|---|
| English (& German) | 294 | 60.5% |
| German | 91 | 18.7% |
| *DEFINE-TRANSLATION* | 101 | 20.8% |

**Table 27 Distribution of CDFs according to language of realization**

Table 27 shows that CDF are predominantly realized in English with only 18.7% of occurrences fully in German. However, it is critical to stress that the 60.5% of CDFs often include a mix of German and English, as illustrated in Example 32 below:

Example 32: Episode realized in a mix of German and English

> T: Now, I have a question (.) If two straight lines are parallel, what can you say about their gradients? [Sm]?
> Sm1: They have the same gradients.
> T: They have the same gradient (.) Can we write that down, please (.) If two straight lines are parallel, they have the same gradient**. <L1de> Oder auf Deutsch**: wenn zwei Geraden parallel sind, dann=
> Sf: =haben sie dieselbe Steigung.

T: haben sie dieselbe Steigung, ganz genau.
Sm2: haben sie das gleiche *k* (.) Kann man das auch sagen? (8) Herr Professor?
T: Ja?
Sm2: Kann man auch sagen, dass sie das gleich *k* haben?
T: Ja genau, sie haben das gleiche k **</L1de>**

Example 32 is coded as EA as it includes an explanation in English, but it is interesting to note that the teacher begins with and elicits a translation to German, which is coded as DFTe. Thereafter, the interaction continues in German with a student asking a question in which he uses the variable *k* as a label for the gradient. This passage illustrates that although English is viewed as the main language of communication, both teacher and students regularly switch to German to ensure comprehension. Throughout the recordings, such language changes occur frequently and naturally, and this pragmatic approach to the use of students' L1 is appropriate in the given context as it ensures that students who may struggle with English are not disadvantaged by the CLIL environment. Additionally, the passage presented in Example 32 can be conceptualized through the lens of the CLIL mathematics classroom as a trilingual discursive space. In this case, the link between two lines being parallel and the gradient is first made in English and then translated into German. After this initial linguistic transfer, the student, Sm2, then asks if is also possible to say that the two lines have the same *k*, which the teacher confirms. Consequently, the mathematical representation of the gradient as a variable is also given.

Further illustrations of the CLIL mathematics classroom as a trilingual discursive space are given in L5 in which German tasks from the textbook are first translated into English and then described using mathematical language, as shown below in Example 33:

Example 33: A passage showing the trilingual discursive space of the CLIL mathematics classroom

T: How would we express, using math, <L1de> "die Hälfte der um sieben verminderten Zahl *x*" </L1de> **Now that in English?**
Sm: The half of=
T: Half of=
Sm: =*x* minus seven.
T: *x* minus seven (.) **How would we write that using math?** <L1de> Die um sieben verminderte </L1de> (4) so this is 150, I believe, a (.) How would you write that?
Sm: *x* minus seven.
T: Mhm.
Sm: In a fraction.
T: Mhm.
Sm: And two.

Example 33 shows an interaction in which the three different modes of communication are explicitly interlinked creating a web of meaning illustrated below in Figure 23:

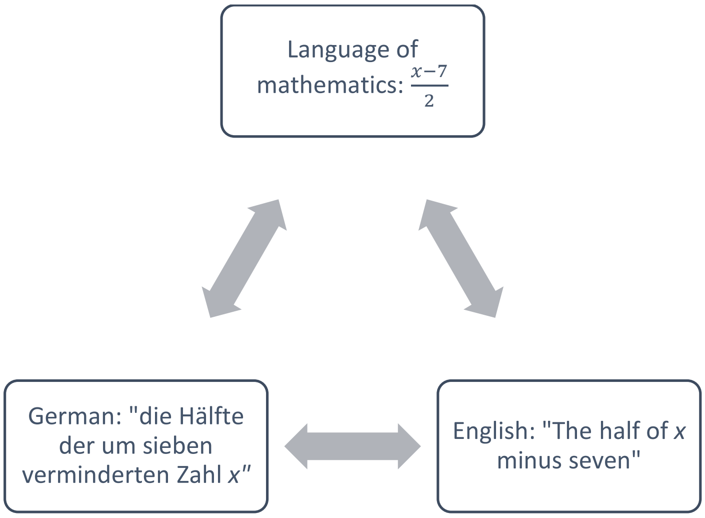



**Figure 23 Interaction of German, English, and the language of mathematics**

Figure 23 shows the interconnection of the different methods of communicating and constructing meaning in the CLIL mathematics classroom. Furthermore, it can be noted that the formulation of such interwoven networks was often integrated explicitly into the learning process, so students would be familiarized with the relevant mathematical knowledge but also the English and German language items.

In conclusion, it can be said that with regard to the use of language, the findings of this study confirm Wilhelmer's (2008: 106) results that use of students' L1 in addition to the target language enhances the learning process. Furthermore, the analysis of passages indicates that the conceptualization of mathematics as a third language in the discourse of CLIL mathematics classroom is not fully misplaced, although much further work is required to elaborate on the basic investigation of this thesis and also examine the implications for teaching practices. In this sense, the findings of this section can be viewed as a foundational starting point from which to engage in further research in this area.

## 6.6. Problematic issues in interpreting the results

This chapter has thus far presented the data and findings of this study, but it is also essential to outline the problematic aspects of the research process in order to provide a framework from which the results can be adequately interpreted. Consequently, this section will describe the challenges and obstacles faced throughout the analysis, so as to ensure that future work can take these factors into consideration when adding to the body of knowledge on CDFs.

Firstly, it should be noted that there is no fixed set of guidelines explaining the coding of CDFs, so the general descriptions presented in previous publications are all that are available for consultation. This means that, while numerous measures were undertaken to ensure consistency in coding, there were a variety of factors that could possibly be interpreted differently. In particular, the following areas were highlighted as possible factors causing ambiguity:

1. CDF episode length: in this case, the main issue at hand is identifying where one CDF episode ends and the next begins. This also includes determining whether a new CDF is a separate episode or different type of CDF embedded in the present episode. In this thesis, a new CDF episode was coded as soon as the interaction moved to a new concept, task, or topic, but this was not always easily identified.
2. The fuzzy boundaries of CDFs: as described previously by Dalton-Puffer (2013: 235), the CDF types are not fixed categories but rather a conceptualization of cognitive thinking processes through speech acts. As such, there will always be a certain degree of interpretation involved in how to code certain passages, especially when applied to a certain subject for the first time. In this thesis, this area was clarified through a precise description of the CDF types in section 4.3.2. as well as a clear presentation of the coding in section 5.4. Nevertheless, it must be acknowledged that a different coding of the data is a possibility.

In addition to these two challenging areas in the coding, it should be mentioned that the transcriptions of the data were coded by a single individual, which means there was no consultation or verification involved. Future research on the use of CDFs in CLIL classrooms can provide greater scientific validity to its findings by having a group review process in place, so the coding process involves numerous experts from the field.

Finally, the relatively small sample size should be taken into consideration before making any major generalization. The study of this thesis was of a qualitative nature, analysing a small sample of seven recorded lessons of a single teacher, with the aim of providing a first impression of how the CDF construct can be used to investigate CLIL mathematics discourse. Subsequently, the findings should be viewed as a starting point for future research rather than a conclusive depiction of CLIL mathematics classes.

# 7. Conclusion

The purpose of this study has been to characterise the classroom discourse of CLIL mathematics classes using the CDF construct. This was achieved through a quantitative overview of the distributions of the different types of CDFs and the realizers as well as a discussion of corresponding passages from the recordings. Furthermore, the data was used to investigate the interrelationships between the different types of CDFs as well as the interwoven use of languages in CLIL mathematics classes. This study was the first to focus specifically on CLIL implemented in mathematics lessons and also only analysed recordings of seven lessons. Consequently, although there are certain tendencies to be found in the data, all results should be interpreted cautiously. This section outlines the main findings of this thesis and discusses implications for teaching practices and future research.

## 7.1. Summary of main findings

The analysis of the data shows that CDFs occur frequently in naturalistic CLIL mathematics classes with a total of 486 CDFs realized across the seven lessons amounting to an average of 69 realizations per lesson. However, it should be noted that the CDFs are not distributed evenly across the lessons and the actual number of realizations ranged from 49 to 112, indicating that this value strongly depends on content and teaching style adopted for the individual lessons. Furthermore, the distribution of the individual CDF types also varied strongly with the four functions *DEFINE*, *DEFINE-TRANSLATION*, *DESCRIBE*, and *EXPLAIN* accounting for over 80% of all realizations. These findings align with the initial characterisation of mathematics as a subject, as the functions *DEFINE* and *DEFINE-TRANSLATION* contribute to clear formulations of mathematical definitions. Additionally, *DESCRIBE* in the mathematical context has a number of important realizations including switching between representations, describing a concept mathematically, and formulating process descriptions. Finally, *EXPLAIN* is the most frequently realized CDF type constituting almost a third of all realizations. This can be attributed to the fact that creating logical links, which is at the core of *EXPLAIN*, is inherent to mathematics. Although the other four CDF types were not realized as frequently, examples from the data were analysed to give an overview of the specific circumstances in which each CDF type was realized, present in Table 23 in section 6.2.

With regard to the realizer, an overview of the distribution presented a very clear picture, namely that with 84%, CDFs are overwhelmingly realized by the teacher and students interactionally with the teacher individually accounting for only a small fraction of all occurrences. Building on the quantitative data, analysis of passages of the recordings confirms that classroom interaction generally follows a pattern of initiation-response-evaluation (Franke, Kazemi & Battey 2007: 229). This means that both the teacher and student utterances are kept relatively short, and there is a constant interchange of information. The teacher acts as a guide through the material, using questions to elicit information from the students. In this manner, the teacher obtains constant feedback on students' conceptual understandings and can correct if necessary. Furthermore, the students receive the necessary scaffolding for constructing sentences with the teacher providing the required linguistic resources.

The fourth research questions addressed the issue of the interrelationship of the CDFs, and in the regard, it can be said the there is a high number of occurrences of embedded CDFs. Additionally, it can be observed that the CDF types *DEFINE*, *DEFINE-TRANSLATION*, and *EXPLAIN* are most frequently realized in embedded form. In the case of *DEFINE* and *DEFINE-TRANSLATION*, this can be explained by the requirement of terminological clarity in mathematics, meaning that these CDF types are often embedded in another CDF episode in order to ensure a certain term or phrase is completely understood. The regular use of *EXPLAIN* in embedded form conforms with the previous studies of Kröss (2011), Hopf and Hofmann (2015), and Brückl (2016). In mathematics, its high use as an embedded CDF can again be attributed to the logical nature of the subject, in which reasoning and deduction are commonly used to facilitate understanding. Overall, it can be said that there are certain tendencies in the interactional realization of different CDF types, but these often differ from subject to subject and also require much further empirical analysis to be confirmed.

The final area of investigation was the use of different languages in the CLIL mathematics classroom. The data showed that CDF episodes are predominantly realized at least partially in the target language, English, amounting to 60% of all realizations. However, there were also a significant number of CDF episodes realized only in German and also a high number of realizations of *DEFINE-TRANSLATION*. Moreover, closer analysis of individual passages exemplified that most CDF episodes were realized in a mix of German and English. These factors all confirm Wilhelmer's finding that "use of the L1 often acts as a support and facilitates students' understanding" (2008:106). Furthermore, the initial results indicate that the conceptualization of the CLIL mathematics classroom as a trilingual discursive space holds some potential for understanding the overall construction of meaning.

The findings of this study are the result of an analysis of data collected from a single CLIL mathematics classroom taught by one teacher. In consequence, it should be noted that these conclusions are a general characterisation of this limited data sample, and further generalizations would require analysis of a greater, diverse sample.

## 7.2. Pedagogical implications and an outlook for future research

The analysis of this study confirms that the CDF construct is a viable tool for investigating the discursive space in which the integration of content and language takes place. In this thesis, the CDF framework has been used as a tool to characterize a CLIL mathematics classroom, and this can act as a first foundation in providing a link between the pedagogies of mathematics and language teaching as illustrated below in Figure 24:

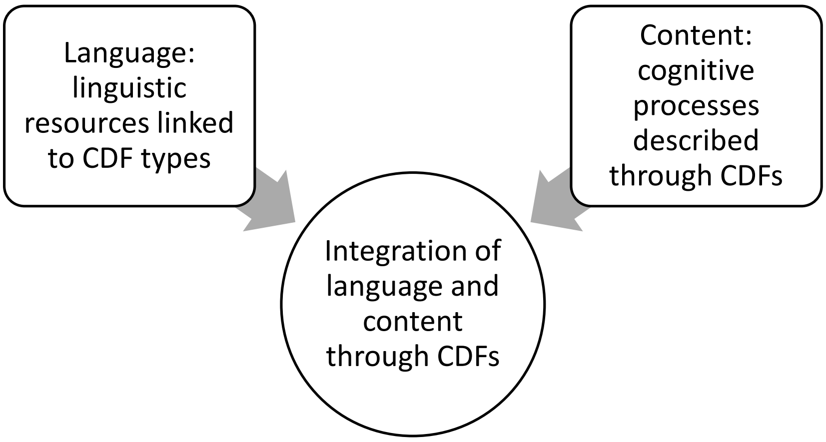



**Figure 24 The CDF construct as a link between content and language**

Figure 24 shows that the CDF construct can act as an explicit connector between content and language. This can be achieved by firstly using the information of this thesis as a foundation for linking mathematical competencies each of the individual CDF types, which approaches integration from the content perspective. Secondly, each CDF type could be ascribed a number of language items used in its realization, so students can be explicitly taught the necessary language skills required for each CDF type, and this incorporates the language perspective. In this context, it would be necessary for future research to provide greater detail on the realization of the different CDF types in the CLIL mathematics classroom as well as compile a collection of specific linguistic skills required for their realization.

In conclusion, it can be said that much further work is required to fully implement the integration of content and language in CLIL classes, but the CDF construct provides a valid first step in the direction of conceptualizing integration. Moreover, at some point, it will be necessary for someone to take the courageous first step of outlining a first subject-specific CLIL curricula, which can then be subjected to criticism and scrutiny. The aim of this thesis has been to contribute in some small way to this overall goal, so that integration remains not only an abstract idea but rather an explicit practice in all CLIL classrooms.

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# 9. Appendix

## 9.1. Abstract

In the context of the European Union promoting multilingualism among its member countries, content and language integrated learning (CLIL) has, since its emergence in the 1990s, developed into a popular educational approach. A great number of studies have highlighted the positive impact of CLIL on language learning, while also showing that there is no detrimental effect on learning content. However, numerous experts in the field emphasize that research in CLIL now needs to move forward to focus on the integration of language and content learning, rather than examining these areas separately. The publication *Discourse in content and language integrated learning (CLIL) classrooms* (Dalton-Puffer 2007) showed classroom discourse to be one of many possible approaches in studying the overlapping space of language and content learning in CLIL lessons. Continuing her work in the field, Dalton-Puffer (2013) also developed the concept of "cognitive discourse functions" to provide a framework for analysing language and content learning in integration.

This thesis aims to address the need for research examining the integration of content and language learning in CLIL classes by applying the cognitive discourse functions (CDF) model to audio-recordings of CLIL mathematics classes. A total of seven mathematics lessons taught in the eighth and ninth grades of an Austrian school were recorded, transcribed, and analysed. The results of this study present greater insight into language used in naturalistic CLIL mathematics classes as well as into the validity of the CDF framework as an appropriate tool in examining classroom discourse. In particular, the results show certain trends in the use of language in CLIL mathematics classroom, for instance the high occurrence of the CDFS *DEFINE*, *EXPLAIN*, and *DESCRIBE* as well as the importance of the interwoven use of different languages in the overall construction of meaning. With these findings, this thesis hopes to provide a foundation for linking the different teaching approaches of mathematics and language and consequently act as a contribution to the development of subject-specific material and curricula in the implementation of CLIL in mathematics.

## 9.2. Zusammenfassung

Im Zusammenhang mit dem Streben der Europäischen Union Mehrsprachigkeit unter ihren Mitgliedsstaaten zu fördern, hat sich Content and Language Integrated Learning (CLIL) seit seiner Einführung in den 1990ern zu einem beliebten pädagogischen Ansatz entwickelt. Eine hohe Anzahl an Studien haben bereits die positive Wirkung von CLIL auf die Sprachentwicklung bei gleichbleibendem Erlernen von Fachwissen gezeigt. Dennoch wird von vielen ForscherInnen betont, dass CLIL weiterentwickelt werden muss und ein größerer Fokus auf die Integration von Fachwissen und Sprache gelegt werden muss, statt auf die individuelle Betrachtung dieser zwei Bereiche. Dalton-Puffer (2007) hat bereits gezeigt, dass Diskursanalyse sich als eine von vielen Ansätzen eignet, den überlappenden Bereich in dem Sprache und Inhalte erlernt werden zu untersuchen. In einer weiteren Arbeit von Dalton-Puffer (2013) wird das Konstrukt "cognitive discourse functions" vorgestellt, das sich insbesondere als Modell für die Analyse von Integration von Sprache und Fachwissen im CLIL Unterricht eignet.

Das Ziel dieser Diplomarbeit ist den derzeitigen Forschungsstand zu ergänzen indem das Konstrukt "cognitive discourse functions" (CDF) von Dalton-Puffer (2013) verwendet wird, um Audioaufnahmen von CLIL Mathematikstunden zu analysieren. Insgesamt wurden sieben Stunden Mathematikunterricht an einer österreichischen AHS in einer vierten und fünften Klasse aufgenommen, transkribiert und anschließend analysiert. Die Ergebnisse der Studie bieten eine Einsicht in die Sprache, die in CLIL Mathematikstunden verwendet wird, sowie auch die Gültigkeit des CDF Konstrukts zu überprüfen. Insbesondere wird gezeigt, dass die CDFs *DEFINE*, *EXPLAIN* und *DESCRIBE* am häufigsten realisiert werden sowie ebenso, dass der verwobene Einsatz der unterschiedlichen Sprachen einen wichtigen Bestandteil der gemeinsamen Sinnkonstruktion bildet.

Mit diesen Ergebnissen bildet diese Diplomarbeit eine Grundlage für die Integration der unterschiedlichen Lehrmethoden aus Sprachen und Mathematik und trägt somit dazu bei, dass fachspezifische Materialien und Lehrpläne für den CLIL Mathematikunterricht entwickelt werden.

## 9.3. Forms

Wien, 1. April 2019.

Sehr geehrter [headmaster's name]!

Im Rahmen meiner Diplomarbeitsstudie an der Universität Wien plane ich in englischer Sprache abgehaltenen Mathematikunterricht zu untersuchen, um näheren Aufschluss über das Mathematiklernen mit Englisch als Arbeitssprache zu gewinnen.

Im Zuge dessen habe ich mich mit [teacher's name] in Kontakt gesetzt, der/die sich bereit erklärt hat seinen/ihren Unterricht für diese Forschungsstudie freizugeben. Im Rahmen dieser Studie werde ich bei sechs Unterrichtsstunden den Sprachgebrauch aufnehmen und anschließend analysieren, um Einsichten in die Funktionen der Sprache im bilingualen Mathematikunterricht zu erlangen. Selbstverständlich werde ich bemüht sein, dass dabei die SchülerInnen in ihrer gewohnten Lernumgebung möglichst ungestört bleiben.

**Alle gesammelten Daten werden anonymisiert und ausschließlich für Forschungszwecke verwendet. Die Tonaufnahmen werden nicht veröffentlicht.**

Ich möchte Sie auf diesem Wege um Ihre Mithilfe durch Erteilung Ihrer Zustimmung zu diesem Vorhaben bitten und bedanke mich bereits im Voraus sehr herzlich für Ihre Unterstützung.

Für Fragen stehe ich Ihnen natürlich jederzeit gerne zur Verfügung.

Mit freundlichen Grüßen,

[student name]
Diplomstudent Anglistik Universität Wien

Wien, 1. April 2019.

Liebe Eltern!

Im Rahmen meiner Diplomarbeitsstudie an der Universität Wien soll der an dem [school name] in englischer Sprache abgehaltene Mathematikunterricht näher beleuchtet werden, um näheren Aufschluss über das Mathematiklernen mit Englisch als Arbeitssprache zu gewinnen.

Im Zuge dessen wurde die Klasse ihres Kindes mit [teacher's name] ausgewählt, um Informationen über bilingualen Mathematikunterricht zu sammeln. Dazu soll der alltägliche Sprachgebrauch aufgenommen und analysiert werden, um Einsichten in die Funktionen der Sprache im bilingualen Mathematikunterricht zu erlangen. Selbstverständlich werde ich bemüht sein, dass dabei die SchülerInnen in ihrer gewohnten Lernumgebung möglichst ungestört bleiben.

**Alle gesammelten Daten werden anonymisiert und ausschließlich für Forschungszwecke verwendet. Die Tonaufnahmen werden nicht veröffentlicht!**

Ich möchte Sie auf diesem Wege um Ihre Mithilfe durch Erteilung Ihrer Zustimmung zu diesem Vorhaben bitten und bedanke mich bereits im Voraus sehr herzlich für Ihre Unterstützung.

Für Fragen stehe ich Ihnen natürlich jederzeit gerne zur Verfügung.

Mit freundlichen Grüßen,

[student name]
Diplomstudent Anglistik Universität Wien

Abschnitte bitte bis spätestens ..... an [teacher's name] retournieren

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Ich habe die Elterninformation über die Studie der Universität Wien zum englischsprachigen Mathematikunterricht zur Kenntnis genommen und bin mit der Durchführung dieser Studie in der Klasse meines Kindes einverstanden.

Name des Kindes: ____________________________

U: ________________________________