Monolingual teachers' interaction with Chinese students in English as the Medium of Instruction (EMI) science classes: an exploratory study of the foreign high school programs in China

Jiangshan An

Department of Education
University of Oxford
St Antony's College



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Supervisors
Professor Ernesto Macaro, Dr Ann Childs

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Abstract

This study is situated in a newly emerging English immersion setting in China where an Anglophone high school curriculum is taught by foreign teachers through English only to local Chinese students. These teachers are termed 'monolingual teachers' in the sense that they cannot use students' L1 in their teaching should they wish to. This setting presents a unique and under-researched EMI scenario due to the monolingual teachers' high English proficiency, which is often found lacking with bilingual teachers (e.g., Tan, 2011), and their inability of using students' L1, a resource often resorted to by bilingual teachers (e.g., Probyn, 2001).

Underpinned by the constructivist view of teaching science (Brooks & Brooks, 1999) and the Interaction Hypothesis (Long, 1996) in SLA, this study makes an interdisciplinary effort by drawing upon expertise in science education and language education to explore the classroom interaction behaviour and the teachers' and students' beliefs about effective teaching of science and English in this new EMI scenario. 9 schools in China were visited, involving 15 foreign science teachers, and approximately 400 students. Classroom interaction was explored through quantitative and qualitative analysis of 12 parameters of the teacher-whole class interaction in 30 video-recorded lessons. Teachers' beliefs were investigated through a teacher beliefs questionnaire, pre-lesson and post-lesson interviews and general interviews. Students' beliefs were examined through post-lesson interviews and a student beliefs questionnaire. A background questionnaire was also administered on the teachers to understand their past teaching experiences and their qualifications.

Results show that while the monolingual teachers held a constructivist view of teaching science and acknowledged the value of interaction for both science and L2 development, their translation of beliefs into practice had limited success. This was demonstrated by the clear teacher dominance in the proportion of the classroom talk and the turn-taking behaviour, difficulties of eliciting linguistically complex output from the students, and a lack of variety of constructivist questioning approaches used. Wait time and teacher nominations, as part of effective teacher questioning, were also used only to a limited degree. Explicit instruction on language had a rather small presence in these lessons, with the meaning of non-technical vocabulary being the main focus without much instruction on the grammatical

features commonly found in science texts. The students rarely asked questions and questions involving higher order cognitive thinking were particularly few. Overall the lessons featured common use of single IRF cycles and the extended IRFs often involved repetitions and reformulations of a previous question. The findings of classroom interaction in this study add to the existing literature of EMI classroom interaction through showing that the teachers' high English language proficiency alone is not sufficient in creating a high level of classroom interaction where opportunities of science and language learning could be available.

The difficulties of creating an interactive and constructivist classroom in this EMI context could be partly explained by the students' beliefs which featured limited acknowledgement of the constructivist idea of teaching science and a lack of thorough understanding of the value of interaction for science and language learning. The students' lack of English proficiency also emerged as a key reason. Other possible explanations included some teachers' lack of clear understanding of the role of students' substantial output, a lack of EMI training and past EMI teaching experience commonly found among the teachers, and some teachers being rather inexperienced in both L1 and L2 contexts. The difficulties observed in the lessons to move forward conversations also provided evidence of the potential value of L1 to facilitate interaction and build a more constructivist classroom, thus creating more opportunities of science and language learning. This was also supported by the students' own voice, where a strong need of L1 was consistently found for various reasons, including accessing previously learnt science knowledge and everyday life experience, clarifying information among peers, and looking for more information online. However, this need of L1 was not always acknowledged by the teachers.

The findings of this study bear several pedagogical implications. First and foremost, teachers' high English proficiency alone does not necessarily lead to a high level of classroom interaction in EMI classes. EMI pedagogy needs to be in place, including the strategies of scaffolding more extensive answers from students, integrating more explicit instruction on language, using a wider range of constructivist questions, providing more wait time and so on. Development of EMI teachers' beliefs on pedagogical issues that are key to the effectiveness of EMI education, e.g., the use of interaction and teacher language

awareness, is also particularly crucial to address. A need to bridge the gap between teacher beliefs and student beliefs was also revealed to ensure students are on board with the teachers' practices. These findings also provide potential implications for bilingual EMI teachers.

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List of abbreviations

EMI	English medium instruction
CMI	Chinese medium instruction
CLIL	content and language integrated learning
MoI	medium of instruction
L1	first language
L2	second language
SLA	second language acquisition
SCT	Sociocultural theory
ESL	English as a second language
EFL	English as a foreign language
IRF	initiation-response-feedback
TLA	teacher language awareness
NS	native speaking
NNS	non-native speaking
LFE	language-focused episodes
T	teacher
Ss	students
T-N	teacher nomination

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Chapter 1 Introduction

1.1 The context of this study

Among the surge of bilingual programs at various educational levels worldwide (Macaro, Curle, Pun, An, & Dearden, 2018), in China, growing effort has also been seen in promoting English medium instruction (Cheng, 2012; Galloway, Kriukow, & Numajiri, 2017; Lei & Hu, 2014; Trube, 2012). The target school programs of this research, the foreign high school programs, are a recent rapidly growing development across China. However, they are rarely explored in academic work.

The pragmatic goal of the foreign high school programs is to prepare students for tertiary education overseas. In the foreign high school programs, local Chinese students study an Anglophone curriculum, such as Canadian British Columbia curriculum, IGCSE, through English. While there is currently a lack of official documentation and statistics on these programs across China, this phenomenon has often made appearance in news. For example, a report on BBC (2016) (https://www.bbc.co.uk/news/business-35533953) highlighted the significant growth of international schools in China where local Chinese families see them as a spring board for their children to attend a university in an Anglophone country. The student body of these foreign high school programs is typically homogenously local Chinese students, which is a key difference from the conventional international schools where usually only expatriate students enrol.

A distinctive feature of this new EMI model is the often high quantity of foreign teachers who cannot use students' L1, i.e., Mandarin, in their teaching, but are highly proficient in English. They are termed 'monolingual teachers' (Macaro, 2018) in this study to highlight the key difference between them and the commonly explored bilingual EMI teachers in the literature who share the students' L1. According to my observation in the fieldwork, most of the monolingual teachers are from majority English speaking countries, such as Canada, the US and the UK. In many of the foreign high school programs there are also Chinese national subject teachers. However, in this current research, the target teacher population is the foreign monolingual teachers.

Many of the foreign high school programs are hosted within the larger facility of a public high school and are owned and operated by a private company. They are often called 'international departments' of a high school. In addition, some foreign high school programs are operated as independent schools without being hosted in a public school. The management of these programs often involves a combination of Chinese nationals and foreign nationals, with the owner of the business often being Chinese, as described in Schuetze & Lin's (2008) report, one of the few academic reports there are on such programs.

Apart from the impact these foreign high school programs make on students' learning, it is acknowledged that there are ideological and social impacts as well. A critical discussion can be found in Schuetze & Lin's (2008) report on the social and ideological issues that are associated with the Canadian offshore programs, which is one type of the foreign high school programs in China. However, it is not the goal of this study to explore the social impacts of the foreign programs.

1.2 The rationale of this study

With the rapid spread of the foreign high school programs in China, more and more students are spending some of their critical learning years (16-18 years old) in these programs. Families are also spending a fortune to finance their children's attendance in the foreign high school programs (Schuetze & Lin, 2008). The stakes are also high in the sense that they have spent substantial time studying a foreign high school curriculum through English and this puts them in a disadvantageous place in the highly competitive local college entrance examination in China. Considering all these high stakes that come with attending a foreign high school program, it is time that empirical evidence, particularly classroom data, is examined to understand the teaching and learning processes in these programs.

Apart from the contextual meaning of this study, another motivator for this study is the monolingual teacher population. The existing literature has rarely explored EMI classes taught by teachers who do not speak the students' L1 to any pedagogical functionality. It is unknown the degree to which the classroom interaction facilitates students' learning of science and English when the teachers' high English proficiency level is unlikely to inhibit their use of classroom interaction but their lack of L1 means they cannot switch to students' L1 if they wish to. Both factors have often been the topic of discussion in the existing EMI classroom literature, as we will see in Chapter 2 Literature Review.

1.3 The aim of this study

Motivated by the rationale explained above, this study aims to examine the teaching and learning in monolingual EMI science teachers' classes through two lenses - classroom interaction and beliefs. As interaction has been widely recognized in both science and language education as an important mechanism through which learning takes place (Long, 1996; Mercer & Howe, 2012; Vygotsky, 1986), the investigation of the features of the classroom interaction between monolingual teachers and their Chinese students forms the core of this study. Drawing upon past literature on classroom interaction behaviour in language education and science education, this study will explore multiple aspects of classroom interaction to gain a comprehensive understanding of the characteristics of the classroom interaction between monolingual science teachers and their Chinese students. Inferences are thus going to be made regarding the extent to which the classroom interaction facilitates science and English learning.

Apart from the investigation of classroom interaction, this study also aims to explore the beliefs held by monolingual teachers and Chinese students about effective teaching of science and English in EMI science classes, which can provide insights to help understand the classroom interaction observed. The degree to which the teachers and students recognize the role of interaction for science learning and language learning will be particularly focused on, drawing upon the widely promoted constructivist teaching approach of science (Brooks & Brooks, 1999) and the long established Interaction Hypothesis (Long, 1996) in second

language acquisition (SLA). The exploration of the language aspect of teacher and student beliefs also includes teachers' and students' estimation of the monolingual science teachers' teacher language awareness (Andrews, 2007), and the extent to which they recognized EMI science teachers as language teachers. Findings of these issues can shed light on how favourable the teacher and student beliefs are for science learning and language learning in their EMI science classes. As beliefs are argued to direct directions (Borg, 2006; Mansour, 2010), it is hoped that certain explanations can be found about the classroom interaction behaviour observed. Comparisons between teacher beliefs and student beliefs can also reveal the divergences between the two, which in the past literature has been found to be an obstacle for the teachers to implement their beliefs (Brown, 2009; Nguyen, 2013).

The main contributions to knowledge this study makes first lie in the examination of the classroom interaction behaviour of monolingual EMI teachers, which eliminates a commonly reported problem with bilingual EMI teachers, i.e., the teachers' unsatisfactory English proficiency. However, their inability of using students' L1 also means L1 is not at their disposal to help out classroom interaction. Another main contribution is the interdisciplinary exploration of both the science domain and the language domain, as compared to the main focus on the language aspect often found in the EMI literature. Lastly, the investigation of teacher and student beliefs about what is effective pedagogical practices makes it possible to find explanations of the classroom interaction observed and enables a deeper understanding of teachers' and students' behaviours. This data triangulation is often absent in classroom interaction studies. A more detailed explanation of the significance of this study is in Section 2.7 of Chapter 2.

1.4 The structure of this study

Following this introductory chapter, the remainder of the thesis is organized as follows: Chapter 2 contains a review of the literature that informed the conceptualization of the current study, including the theoretical perspectives and past empirical work in regard to classroom interaction and teachers' and students' beliefs. Considering the interdisciplinary interests of this study, theoretical frameworks and empirical findings from both language education and

science education were consulted. Chapter 2 also provides detailed justification of the significance of exploring the monolingual EMI teacher population.

Chapter 3 details the research methodology of this study, including the sampling strategies and sample characteristics, the instruments, the procedures for data collection and analysis, and important ethical considerations.

Chapters 4, 5 and 6 present the findings of the study. Chapter 4 presents the findings on classroom interaction. Chapter 5 and Chapter 6 respectively presents the findings of the teachers' beliefs about effective teaching of science and English in EMI science classes and the students' beliefs on the same matter.

The thesis ends with a discussion and conclusion chapter, Chapter 7, which provides a coherent narrative and makes connections among the findings for classroom interaction, teachers' beliefs and students' beliefs. Interpretations of the findings are made to infer the quality of learning for science and English in the EMI science classes, with reference to previous literature. Difficulties of creating a favorable learning environment for science and English in this context are also identified.

Chapter 2 Literature Review

This chapter situates the target school program of this study, i.e., the foreign high school programs in China, within the literature of bilingual education where the medium of instruction, or part of it, is the students' second or foreign language. It then proceeds to provide the theoretical frameworks that underline the exploration of classroom interaction and teachers' and students' beliefs in this study, where expertise is drawn from both science education and language education.

2.1 The growth of programs using students' L2 as the Medium of Instruction (MoI)

In many regions of the world there has been an unprecedented growth and interest in teaching academic subjects, such as science, maths, history, through a language that is not the first language of the students in the classroom, or at least not of the majority of the students (Coleman, 2006; Graaff, Koopman, Anikina, & Westhoff, 2007; Lorenzo, 2007; Morton, 2018). This approach is labelled differently in different contexts. For example, in North America, they are labelled 'immersion' (Cammarata & Tedick, 2012) or content-based instruction (Met, 1999; Genesee, 1987). In Europe, they are almost invariably named Content and Language Integrated Learning (CLIL) classrooms (Pérez-Cañado, 2012). In Asia, South America and the Middle East, the term English Medium Instruction (EMI) is widely used in both secondary and tertiary education (Macaro, Curle, Pun, An, & Dearden, 2018). Each program possesses its own agenda and pedagogical practice (Pérez-Cañado, 2012; Zarobe & Catalan, 2009), but the unifying feature is that one or multiple content subjects is taught through a second or foreign language of the students.

2.1.1 French Immersion programs and content and language integrated learning

The French immersion programs in Canada are considered the most well-known early endeavour in using students' L2 as the medium of instruction (MoI), aiming for students' full French proficiency by teaching academic subjects in it. These programs started in the 1970s as a response to English speaking parents' demand for schooling that equips their children

with effective French language proficiency for better career prospects in Canada (Swain & Lapkin, 1982).

Although there are different types of French immersion programs, depending on the instructional time devoted to L2 and the starting age (Collier, 1989), the general research findings show that the French immersion programs are significantly more effective than traditional French L2 language classes in improving students' French proficiency (Cummins & Swain, 1986; Lazatuk, 2007; Swain & Lapkin, 1982). Moreover, despite the use of L2 as the MoI, immersion students' academic performance has been found to be at a similar level to their non-immersion peers (Lazatuk, 2007; Swain & Cummins, 1979). This suggests that the use of L2 does not appear to compromise students' subject content learning.

From the psycholinguistics view, the success of the French immersion programs in promoting the learning of French can be explained by Krashen's (1982) Input Hypothesis, Swain's (1985) Output Hypothesis and Long's (1996) Interaction Hypothesis. Through learning subject matter in an L2, students have more opportunities to receive comprehensible L2 input, produce their own output, and to negotiate meaning with their teachers and peers through which input and output can be modified and feedback to their own L2 use is provided. Although the learning of the L2 is not directly focused on in subject lessons, unlike in the traditional L2 language classes, the incidental learning of the L2 seems to be effective (Genesee, 2006). More elaboration of the Interaction Hypothesis is given in Section 2.3.3 later.

The success of French immersion programs makes them a reference point for L2 programs in other parts of the world, such as the CLIL programs in Europe. As the name explicitly points out, CLIL has dual goals, namely promoting students' learning of both academic subjects and the foreign language (Coyle, Hood, & Marsh, 2010). However, in comparison to the French immersion programs, in CLIL programs, usually only a few subjects are taught in students' L2, thus providing less exposure and making it different from immersion programs in not aiming for native-like proficiency (Lasagabaster & Sierra, 2009).

2.1.2 English as the medium of instruction (EMI) programs

Driven by the internationally recognized status of the English language, the success of French immersion programs, and the motivation of internalization at universities in many parts of the world, EMI programs have become a fast-growing worldwide phenomenon.

According to Macaro (2018), the working definition of EMI is:

> *'The use of the English language to teach academic subjects (other than English itself) in countries or jurisdictions where the first language of the majority of the population is not English (p.1).'*

In recent years EMI has played a rapidly expanding role in schooling to accommodate the demand from students in non-English speaking countries in the hope of receiving education in English (Baharom & Ying, 2010; Dearden, 2014; Hu, 2009; Kong, 2009). One example of the frequently researched EMI school contexts is the EMI secondary school education in Hong Kong. The main aim is that by using only English as the language of instruction to teach all subjects (except Chinese and Chinese History), students' English proficiency will be promoted alongside subject matter learning, which then prepares them for tertiary EMI education (Lo & Macaro, 2012).

The overall research evidence investigating the effectiveness of the EMI schools in Hong Kong seems to suggest that although EMI students' English proficiency is often reported better than their non-EMI peers, their academic performance suffers. Yip et al.'s (2003) longitudinal quantitative study compared EMI students' and Chinese as the medium of instruction (CMI) students' performance in science subjects and found that in spite of EMI students' higher initial ability in science and English, they did not perform as well as the CMI students in both science subject matter and the language of science. Similarly, the recent meta-analysis by Lo and Lo (2013) also confirms that although EMI students' performance in English is better than CMI students, their academic achievement is lower despite a possibly higher entry level. This suggests that unlike the French immersion programs in Canada, EMI education in Hong Kong

has struggled to fulfil the dual aims – enhancing students' learning of English but not compromising the learning of academic subjects.

The contrasting findings of the EMI programs in Hong Kong and the French immersion programs in Canada show that the effectiveness of bilingual programs may vary in difference contexts and as some researchers (e.g., Dalton-Puffer, Nikula, & Smit, 2010; Dupuy, 2000; Jeon, 2012; May, 2008) have pointed out, caution needs to be exercised against extrapolating findings from one context to another. This leads to the exploration of a new EMI context, i.e., the foreign high school programs in China.

2.2 Foreign high school programs in China

In the recent years, China has witnessed a rapid rise of EMI programs for local Chinese students across the country where a curriculum of an Anglophone country is followed and often taught by a high number of foreign teachers. These programs often exist in what are termed 'international departments' located within public high schools, or in independent private schools. Students attending the foreign high school programs typically plan to transition to tertiary education in an Anglophone country after high school. Examples of the foreign high school curricula taught in these programs include Canadian provincial high school curriculum (e.g. British Columbia, Alberta), IGCSE, A-level, IB, AP. Apart from the foreign teachers, there are also often teachers who are bilingual Chinese nationals in these programs.

While there are no official statistics describing the spread of foreign high school programs in the country, news reports and research from consultancies have frequently commented on the rapid growth of the foreign high school programs in China. As cited in Liu's (2015) news report, 90 international programs are authorized in public high schools and possibly many more without official approval. In Beijing, until 2014 there were 24 high schools with such programs, and in Shanghai, 11 public and 10 private high schools were approved to offer international programs (Liu, 2015). The popularity of such programs has also spread to

smaller cities (Liu, 2015). A report published on BBC (2016) also described that international schools are on the rise in Asia and '*the big story is in China*', where it specified that '*China has some 530 English-medium international schools, catering for 326,000 students'* and *'more local families are using international schools….as a springboard to getting places in UK and US universities'.* Similarly, The PIE News (2015), quoting data gathered by International School Consultancy (ISC), also pinpointed the growing phenomenon of private bilingual schools in China offering a foreign curriculum to Chinese nationals:

> *'China has the most English-medium international schools, 526. It has also seen the biggest growth in the number of institutions, increasing by 218 in the four years from September 2011, according to ISC Research… There is insatiable demand by Chinese nationals for English-medium education in China and, with such an enormous number of Chinese families able to afford high private school fees.' (p.1)*

As there is a lack of official documentation of these programs, it is hard to provide a comprehensive introduction of them. However, based on the news reports and my fieldwork, it seems most of the foreign high school programs are operated by private educational agencies and the school fees are usually high. Apart from the clear motivation of studying overseas after high school, another reason pushing students to opt foreign high school education, as discussed in Gordon & Liu's (2014) study, is the severe competition for entrance to universities in China.

2.2.1 Monolingual teachers

As mentioned above, in many of the foreign high school programs in China, there is a high quantity of foreign teachers who cannot use students' L1, i.e., Mandarin, in their teaching should they wish to. They usually speak English as their most proficient language and typically come from Canada, the UK and the US. In their classes the medium of instruction is exclusively English. They constitute a key characteristic of this EMI scenario which differentiates it from most of the secondary school EMI programs discussed in the existing literature.

These teachers are termed ‘monolingual teachers’ in this study. The term ‘native speaker teachers’ is not used due to the connotations attached to the latter (Llurda, 2005; Moussu & Llurda, 2008), and the potential difficulty of defining what counts as a person’s native language (Andrews, 2007). Non-native English speaking teachers who may be highly proficient in English may find themselves in a teaching situation in which they do not speak their students’ L1 and thus also qualify as monolingual teachers. However, these non-native English speaking teachers are multilingual individuals. Thus, in this study, the term ‘monolingual teachers’ is proposed to take into consideration these matters and to refer to the teachers who cannot switch to their students’ L1 in their teaching. Of course, monolingual teachers may well be bilinguals or even multilinguals who speak languages other than English. The definition of them is simply based on whether they can speak the L1 of the students.

In the wider literature of English as an international language and global Englishes, there has been growing discussion about recognizing the legitimacy and merits of teachers who are multilinguals and re-evaluating the epistemic stance of SLA research to consider both language learning and language use in society (Elder & Davies, 2006; Kirkpatrick, 2011; May, 2014; Rose & Galloway, 2019). Along this line of research, many scholars have also been questioning the monolingual bias underpinning the traditional linguistic-cognitive model of SLA (Ortega, 2014). It needs to be mentioned here that although this study uses the term ‘monolingual teachers’, the teachers may be multilingual individuals who speak not only English but also other languages. This can bring pedagogical benefits to the students (Kirkpatrick, 2011; Rose & Galloway, 2019) and their possible multilingual background is not meant to be reduced by the name of ‘monolingual teachers’. Nor does this study promote the native-like competency and see it as the standard for EMI teachers. The term is used here to contrast the teachers in this study with the bilingual teachers commonly explored in the existing EMI literature. One of the frequently described classroom interaction behaviours of the latter in the literature is switching to students’ L1 to fulfil a variety of functions, as explained in Section 2.4.1 later. Thus, the monolingual teachers’ inability of resorting to students’ L1 in classroom interaction, is a major characteristic of the target teacher population of this study and is where a key contribution of this study lies. Thus, the term ‘monolingual teachers’ is used to serve the purpose of this study.

It seems so far that only in these foreign high school programs in China do monolingual EMI teachers exist in large quantities teaching homogeneous groups of local students at the secondary school level. After extensive search of literature, there has been little published academic work in international research journals that explored this EMI scenario from a pedagogical point of view, or EMI contexts with monolingual teachers. Thus, this study makes an initial attempt to explore the teaching and learning in the science classes featuring monolingual EMI teachers in the foreign high school programs in China, and the teachers' and students' beliefs about effective teaching and learning. More contrast between monolingual EMI teachers and bilingual EMI teachers with reference to the existing literature is presented in Section 2.4 later, together with the pedagogical implications monolingual teachers may bring to the learning of subject content and English in EMI contexts.

2.2.2 The decision to focus on science EMI classes

Before delving into the relevant literature, it needs to be specified that this study focuses on science subjects in the foreign high school curricular (e.g. chemistry, biology, and physics). The reason is because of the recognized different registers between science subjects and humanities subjects. As Lo (2014) demonstrates, the styles of language (e.g., vocabulary, syntax and discourse) used in different academic subjects are different and for different purposes. Such styles of language are called 'registers' (Halliday, 1978). The register of each subject is usually a result of the knowledge structures involved in that subject, such as classification, evaluation and so on (Kong, 2008). It is speculated that humanities subjects may involve more descriptions and narratives (Schleppergrell, Achugar, & Ote'iza, 2004), and thus language used to explain chronological order, description of places and so on could be particularly important. In contrast, in science subjects charts, equations, and experiments in labs are often used to illustrate abstract concepts, logical relationships and universal phenomena (Lemke, 1990; Martin, 1991), and the language features to express logical relationships, such as comparing and contrasting, inducing the overall trend and so on, could be particularly important for science learning. The language of science is also specialized through certain discourse features, such as lexical density, nominalization and grammatical metaphor (Fang, 2005; Halliday, 1993; Martin, 1991). These linguistic devices, such as nominalization, may be particularly challenging, for both L1 and L2 students, because through

nominalization the description of a process which could have taken a clause is condensed into a single noun or noun phrase, such as ‘resultant force’ in physics and ‘oxidation’ in chemistry.

It is argued that the teaching of language, including the role language plays in the subject learning, the language features that may cause problems and so on could be very different between science subjects and humanities. As the teaching of the language in subject lessons is one main focus in this study, the distinction between humanities and science subjects are made and due to the capacity of a doctoral research and pragmatic reasons, this study will only focus on science subjects. Another reason is that there has been ample amount of research in the L1 science context and a growing amount of research in L2 EMI science contexts in other parts of the world with which comparisons can be made.

2.3 Classroom Interaction in EMI science classes

The value of interaction for learning has been long documented in Sociocultural Theory (Vygotsky, 1986), and also widely discussed and recognized in the area of science education informed by constructivism (Alexander, 2004; Mercer & Howe, 2012; Wood, Bruner, & Ross, 1976), and in language education (Ellis & He, 1999; Gass & Mackey, 2006) in the line of work following Interaction Hypothesis (Long, 1996). As classroom interaction is one of the key focuses of this study, this section provides a detailed discussion of the existing theoretical frameworks on interaction, which underpins this study.

2.3.1 Sociocultural theory (SCT)

The line of research on Sociocultural Theory (SCT) provides the fundamental theoretical understanding of the role of interaction in learning, which has also been used as a conceptual framework by scholars for understanding how the learning of science and language takes place. As Vygotsky (1986) states, cognitive developments originate from social contexts and proceed to individual mental activities, termed respectively as intermental plane and the intramental

plane. During social interaction with others, a learner can be assisted by a mentor or a more competent peer to accomplish a task which is beyond the learner's current ability but can be accomplished independently later without assistance. This process of providing temporary help is termed 'scaffolding' and it is applied within 'the zone of proximal development' where the learners are able to make progress through scaffolded interaction (Vygotsky, 1978; Wood, Bruner, & Ross, 1976). The concept of scaffolding has also been applied in understanding learning in the classroom contexts by educationalists (e.g., Gibbons, 2002; Maybin, Mercer, & Stierer, 1992). This Vyostskian conceptualization of learning has also been applied to science classrooms to understand how science learning takes place through classroom interaction and collaborative dialogues between teachers and students, and among students themselves (e.g., Mercer & Littleton, 2007; Mercer & Howe, 2012; Mercer, 2010).

SCT has also cast light on understanding the role of language in facilitating learning at both the intermental plane and intramental plane, and this has been used by scholars in SLA to understand the process of language development. In SCT, language is argued to function as a mediation tool for engaging in social interaction with others and managing cognitive activities within one's own mind (Vygotsky, 1986). This use of language to perform higher-order mental functions to develop, regulate and direct cognitive activities has been widely explored in SLA (e.g., Lantolf & Thorne, 2007; Lantolf, 2000; Lantolf & Appel, 2013; Swain & Lapkin, 2000; Swain & Lapkin, 2002). Swain in her (2010) study also proposed the term 'languaging' to depict this process of using language to facilitate thinking. She also argued for the suitability of applying this concept in learning science or other subject matter.

2.3.2 Interaction in science learning: constructivism

As proposed in SCT, learning starts from a dialogic and interactive process. This notion of collaborative talk provides the conceptual basis of the constructivist view of learning, a view recently highly promoted in science education in many parts of the world (e.g., Haney & McArthur, 2002; Jenkins, 2000; Mansour, 2009; Prawat, 1992; Sampson et al., 2013).

Constructivism originated as a theory of knowledge and learning. It views students as the centre of learning and students should take an active role in the reconstruction of their

knowledge (Driver, 1989). Ample implications have been made based on the constructivist idea on classroom teaching practices where students are seen as playing a key role of learning (Ernest, 1998; Gagnon & Collay, 2001; Haney & McArthur, 2002; Jenkins, 2000; Palmer, 2005; Prawat, 1992). Among the constructivist view of learning, there are several varieties of constructivism (Phillips, 1995) and the two branches that are most consulted in respect to learning in classrooms are cognitive constructivism, developed based on the ideas from Piaget, and social constructivism, which is based on the ideas from Vygotsky. Now the discussion turns to the distinction between cognitive constructivism and social constructivism, the latter of which is the theoretical basis of the exploration of classroom interaction behaviour in this study.

The cognitive constructivist view of learning sees learning as a process that primarily takes place within the individual learners (Osborne & Wittrock, 1985; Piaget, 1978). Learning is triggered through learners' physical, mental or social experiences and is completed through learners' own interpretation of these experiences. In this process, a teacher's role is limited to providing these experiences. In contrast, social constructivism, which also highlights the active role of the learner and sees learning as a process of the learners' own reconstruction of their knowledge, specifically argues that learners interpret their experiences and construct their knowledge through interaction with other people, particularly the more knowledgeable people (Ernest, 1998; Gredler, 2001). Thus, learning is seen as a social experience and learners' meaning making of their experiences is aided by interaction with others. In the classroom context, the teacher, as a more knowledgeable other, have a key role in creating opportunities where students can negotiate and make sense of their experiences with peers and the teacher (Brooks & Brooks, 1999), and act as a mediator of the students' social and physical experiences (Taylor, Fraser, & White, 1994). Thus, the role of communication with the teacher and peers are seen as central to learning in social constructivism. In the process of communication, teachers' understanding of the students' existing conceptions, students' active inquires and elaboration of their ideas are essential ingredients to facilitate the accommodation of the new experiences into the students' existing knowledge structure, i.e., the reconstruction of their knowledge (Beck, Czerniak, & Lumpe, 2000; Gil-Pérez, Guisasola, Moreno, Cachapuz et.al, 2002; Haney & McArthur, 2002).

The highlight in the social constructivist view of learning on the role of interaction with others to induce conceptual change in students provides the theoretical justification of the focus on classroom interaction in this study. It is through teacher-student interaction that teachers become aware of students' prior conceptions, confront their misconceptions and lead them to modify their existing understandings through resolving conflicts between their misconceptions and new knowledge (Morton, 2012). Thus, interaction plays a significant part in learning in the social constructivist pedagogies and therefore the exploration of classroom interaction in this study is considered bearing significant value to understand the learning process in the EMI science classes in the foreign high schools in China.

In the existing literature, the constructivist model of teaching is often contrasted with transmissionary model of teaching. In the transmissionary teaching approach, teachers play an active role in transmitting knowledge to students, who are seen as passive receivers of the knowledge with no previous understandings or opinions about the topic (Fox, 1983; Taylor et al., 1994). On the contrary, the constructivist teaching approach is based on the belief that learners have developed everyday conceptions on their own about the world before classes and the learning of science takes place through students' modifications of their existing perceptions to accommodate the new experience when their existing understanding is incompatible with the accepted scientific knowledge (Hohenstein & Manning, 2010).

Guided by the theoretical foundation of SCT and the social constructivist view of learning, classroom-based empirical studies have suggested teachers' use of certain interactional strategies are beneficial for students' academic progress in science and math classes. For example, Alexander, Mercer, Littleton and colleagues discovered that science and math teachers' use of certain interactional strategies is associated with students' better educational achievements (Alexander, 2000, 2004; Littleton & Mercer, 2013; Mercer & Littleton, 2007). They then developed an influential practical teaching approach, named Dialogic Teaching, giving guidance to the strategic use of dialogues and interaction between teachers and students to realize conceptual change. The overarching principle of Dialogic teaching is providing ample opportunities for learners to substantially articulate their thinking, which serves as the basis for instruction. The typical behaviours of Dialogic Teaching include using questions to elicit extensive and thoughtful answers, maintaining students' participation in extensive

dialogues where follow-up questions are asked based on students' answers, helping students to explore their own conceptions until they are clear and confront their misconceptions by using examples, experiments and so on (Alexander, 2004; Littleton & Mercer, 2013; Mercer & Littleton, 2007).

In the promotion of students' use of their own words to elaborate their ideas, Dialogic Teaching also highlights the importance of introducing necessary vocabulary and other language forms and allowing sufficient wait time (Littleton & Mercer, 2013). This is particularly relevant to the context of this study where the medium of instruction is students' L2. Only by equipping EMI students with the language needed for producing extensive answers and providing enough wait time for them to form their answers can teachers know students' perceptions and lead them to restructure their knowledge.

The idea of promoting the use of dialogue can also be found in Mortimer & Scott's (2003) influential work where a multi-level framework was developed to characterize the nature and patterns of teacher-student discursive interactions in science classrooms. This framework is also based on SCT and is developed from empirical analyses of classroom talk. Recommendations are made in their work that the use of a combination of communication approaches (e.g., an authoritative approach vs. a dialogic approach, an interactive approach vs. a non-interactive approach), particularly the use of dialogue, is associated with higher learning outcomes. It is also recommended that students should be given the chance to talk about their own scientific views and talk their way into the science perspective.

In both Dialogic Teaching and Mortimer & Scott's seminal work, it is also acknowledged that, despite all the benefits of using interaction, interaction does not need to be used all the time in classes. Teachers' monologues and authoritative talk can also be effective and appropriate, depending on the purpose of the teaching. For example, Mortimer & Scott (2003) argued that introducing or teaching new language items required in explaining science ideas would require some form of authoritarian approach along the dialogic-authoritarian dimension to provide specific information. Thus, the use of dialogue and the use of monologue should be decided according to what is the best for the occasion (Littleton & Mercer, 2013).

The engagement in practical activities is another important component in the constructivist approach of teaching science to facilitate students' construction of knowledge (Jenkins, 2000; Marshall, 1992). In science classes, the use of lab lessons is the typical form of engaging students in conducting practical activities. Based on the constructivist view, students should be encouraged to conduct experiments themselves to explore new knowledge and provide their own reasoning of the results. Teachers should prioritize the meaning making process rather than the result (Kang & Wallace, 2005). Thus, a minds-on approach is promoted. In contrast, in the transmissionary view, practical activities are not used as an integral part of the meaning making process but instead as a separate entity to the main lessons, usually following up complete lessons as consolidation (Tobin, 1986). An example of the transmissionary use of practical work is a recipe-like way of conducting practical work, where the students follow a set of given instructions and procedures without exploring the meaning or reasons behind what they observe (Abrahams, 2010). It is acknowledged, however, both the constructivist and transmissionary use of practical activities could benefit students' learning and both have a place in teaching (Abrahams, 2011; Tobin, 1986). What needs to be specified is that if only transmissionary use of practical activities is implemented, that is considered unfavourable for students' science learning (Abrahams, 2011; Tobin, 1986).

2.3.3 Interaction in language learning: Interaction Hypothesis

Apart from the science domain, the role of interaction for language learning has also been widely explored in the field of language education. The Interaction Hypothesis (Long, 1996), which is also referred to as the interaction approach or the interaction model in SLA, suggests that through interaction, language learners have opportunities to notice differences between their own formulations of the target language, i.e., their interlanguage, and the target forms, and receive or provide feedback which lead to modifications of input or output. It is also considered a key theoretical framework underpinning the potential effectiveness of EMI education for promoting L2 development, which will be elaborated below.

In the interactionist framework, it is argued that through negotiation of meaning, i.e., the process where interlocutors adjust their utterances to solve communication breakdowns (Long, 1996), favourable conditions are created for L2 acquisition. As a number of studies have demonstrated (e.g., Ellis & He, 1999; Gass & Mackey, 2006; Gass, Mackey, & Ross-Feldman, 2005; Pica, 1994), these favourable conditions are built on three components in interaction: 1).comprehensible input that is either pre-modified or modified through negotiation of meaning; 2).pushed output where learners test their hypotheses about language and modify their interlanguage; and 3).feedback from one interlocutor to another, signalling a lack of understanding, which elicits modified input or pushed output. Through negotiation of meaning, learners will be triggered to notice the gap between their interlanguage and the target forms and realize the form-meaning relationships.

Regarding the role of comprehensible input, sufficient exposure to input the meaning of which is comprehensible to learners and the form of which is just beyond their current interlanguage is considered most helpful for L2 acquisition. Krashen (1982) has termed this as ' i+1'. This means that in the classroom situation, the teachers' input needs to possess such features to favour students' L2 acquisition. In addition, research also shows that input that is modified through negotiation of meaning, i.e., modified by learners asking for clarifications, is highly beneficial for L2 comprehension (Pica, Young, & Doughty, 1987). Both teachers' pre-modified input and input modified through negotiation of meaning can manifest itself through paraphrasing, repetition, using synonyms and antonyms, giving examples, simplifying vocabulary etc. (Chaudron, 1983; Gass & Mackey, 2006; Long, 1985).

Another aspect of interaction that leads to L2 acquisition is learners' output, particularly output that is modified through negotiation of meaning, as a response to signals of a lack of comprehension from other interlocutors (Ellis & He, 1999; Swain, 1995; 2000). In the classroom context, they would be the teacher or peers. Swain (1995) proposed Output Hypothesis and argued that through producing output learners have the chances to test their hypotheses of certain language forms and notice the gap between their interlanguage and the target forms. This process is necessary for L2 development, particularly for the development of L2 accuracy.

Both modified input and modified output in the process of negotiation of meaning are often initiated by feedback from another interlocutor. In the classroom context, a student can provide feedback, e.g., clarification requests, to a teacher's utterances, which can lead the teacher to modify their utterances to make them more comprehensible to the students. Similarly, a teacher can also provide feedback to a student's utterances to request modifications of their output through using recasts, clarification requests, repetition, confirmation check and so on, which are common types of feedback in the Interactionist framework (Gass & Mackey, 2006).

EMI classes are believed to have an advantage to create these favourable conditions to promote L2 learning. It is argued that the communication of subject content knowledge could provide ample opportunities for students to receive meaningful input that is comprehensible, produce output and negotiate meaning with the teachers and peers where feedback can be provided (Cammarata & Haley, 2017; Coyle, 2007; Dalton-Puffer, 2007; Nikula, Dalton-Puffer, & García, 2013). In fact, the effectiveness of French immersion programs in promoting students' French proficiency has been widely argued to be largely attributed to the ample opportunities of incidental learning of the language created during the communication of the subject content (Cammarata & Haley, 2017; Genesee, 2006; Lazatuk, 2007; Swain & Lapkin, 1982).

Because of the significance of interaction on learning, including the learning of subject knowledge and language, ample studies have been conducted to explore the classroom interaction behaviour in bilingual programs. The next section presents the empirical research in this area.

2.3.4 Empirical evidence of classroom interaction in EMI classrooms

As elaborated above, interaction is one of the main mechanisms that contribute to learning in classrooms. In EMI and CLIL contexts, exploration of classroom interaction and discourse has attracted considerable attention, particularly at the secondary school level (e.g., Dalton-Puffer, 2007; Escobar Urmeneta & Walsh, 2017; Evnitskaya & Morton, 2011; Lo & Macaro, 2012; Maxwell-reid, 2017; Nikula, Dalton-Puffer & García, 2013). Most of the existing studies

feature bilingual teachers who share the same L1 with their students. The existing findings of the general classroom interaction patters are presented first in Section 2.3.4.1, followed by teacher questions in Section 2.3.4.2 and student questions in Section 2.3.4.3. Lastly, in Section 2.3.4.4, the literature on teachers' explicit instruction on language in EMI/CLIL classes is discussed.

2.3.4.1 Explorations of classroom interaction

Studies on classroom interaction and discourse constitute an important body of research in the EMI and CLIL contexts at the secondary school level. Considerable contribution in this area has come from classroom-based research in EMI secondary schools in Hong Kong, where a teacher dominated interaction pattern is often reported. Studies on CLIL classrooms in Europe have also made significant contribution in understanding the language learning and use, and knowledge construction through classroom interaction.

Findings about classroom interaction in EMI secondary schools in Hong Kong often show a low level of interaction between the teacher and students, strong teacher dominance, limited student participation and a tendency towards a transmissionary teaching approach. Yip, Coyle & Tsang's (2007) study, comparing CMI (Chinese medium instruction) and EMI science classes in junior secondary schools in Hong Kong, revealed that EMI science teachers adopted a more lecturing-like approach and used less interactive instructional activities than CMI science teachers. EMI teachers were found to often use short and fragmented speech in class, which was commented as insufficient to present abstract or complex content ideas. In comparison, in CMI science classes students were found to be more active in classes and ask more questions. A similar classroom interaction pattern was also observed in Lin's (2006) study. Wannagat (2008) also disovered that students rarely initiated teacher-student interactions in the EMI history classes in secondary schools in Hong Kong, as compared to CLIL history classes in Germany. Built upon both quantitative and qualitative data with a more fine-grained analysis framework, Lo & Macaro (2012) took a step further to examine the change of classroom interaction pattern from Grade 9 CMI classes to Grade 10 EMI classes in Hong Kong. They reported that, as compared to CMI classes, EMI classes featured less use of teacher questions, heavier teacher talk, little space for student talk, less use of extended dialogues, and less space for scaffolding and negotiation of meaning. The same pattern was

also found in Pun's (2017) work, focusing on EMI science classes in secondary schools in Hong Kong.

Regarding the classroom-based research in CLIL in Europe, as Nikula et al. (2013) summarized, there are three main areas of focus – language learning opportunities in classroom interaction, the social-interactional aspects of CLIL classroom interaction, and subject content knowledge construction process in classroom interaction. Similar to the findings in the EMI context in Hong Kong, Dalton-Puffer (2007) also summarized that CLIL classrooms feature heavy teacher talk and minimal presence of extended teacher-student dialogues. This pattern of a lack of substantial output from students has also been long documented even in the highly regarded French immersion classrooms (Harley, Allen, Cummins, & Swain, 1990; Mantello, 1996).

In the studies exploring subject knowledge construction in CLIL contexts, conversation analysis approach is often adopted, together with socially-situated learning models, such as communities of practice (Dalton-Puffer, 2007; Evnitskaya & Morton, 2011). In-depth examination is often provided of excerpts of teacher-student dialogues, mostly featuring case study of one or two teachers. Common areas of effective strategies identified include making use of multi-semiotic resources (Evnitskaya & Morton, 2011; Forey & Polias, 2017), students' L1 to elicit student output and facilitate communication of meaning (Tavares, 2015) and so on.

In the bigger picture of the literature on exploring classroom interaction in various contexts, including language classes, L1 subject classes and EMI classes, the framework of IRF (initiation-response-feedback) sequences has been widely used (e.g., Atkins, 2001; Nikula, 2007; Nunn, 2001; Todd, Chaiyasuk, & Tantisawetrat, 2008; Wells, 1993). IRF is a well-established teacher-led classroom conversation structure, first proposed based on empirical data in L1 subject classrooms by Sinclair & Coulthard's (1975). The identification of extended IRFRF chains was initially raised in Mortimer and Scott's (2003) work and they argued that the structure of students providing further responses after teacher's feedback is a typical form of classroom discourse with a more dialogic nature. This extended IRFRF structure allows teachers to explore students' ideas in more detail. To elicit further responses from students, they argued that the teacher's feedback could be a simple repetition of student's previous response, elaboration or paraphrase of the student's answer, or a request for elaboration.

This recognition of the value of IRFRF chains also aligns with the social constructivist view of learning, where the central role of students' existing knowledge and student participation for learning is highlighted (Osborne & Dillon, 2010). Also among the body of research arguing for the benefits of extended IRFRF sequences is Wells' (1993) work situated in L1 science classes and Hall's (1997) work about Spanish L2 language classes where teachers' use of additional questions based on student responses and requests for further elaborations led to more active and creative use of Spanish from students. Also in the support of the value of IRFRF sequences is Dialogic Teaching (Alexander, 2004; Mercer, 2007), where, as elaborated earlier in Section 2.3.2, the extended dialogues have been recognized as beneficial for students' science learning.

The understanding of how classroom interaction in EMI classrooms promotes the learning of English can also find inspirations from the literature on language classrooms. Features of student talk in language classrooms have been identified to be indicative of the quality of interaction for facilitating students' language development. Macaro, Granham & Woore (2016) argued that two key indicators of the quality of teacher-student interaction in L2 classrooms are substantial student turns and complex linguistic features in student output. They further argued that one indicator of the linguistic complexity level of student responses is the degree of the use of verb phrases or subordinate clauses. Thus, the noun-verb ratio in student output was recognized as useful to reflect the linguistic complexity level of student output, which can in turn reflect the quality of teacher-student interaction in facilitating L2 learning. In Macaro and Mutton's (2002) study, exploring modern language student teachers' classes with secondary school students in England, the noun-verb ratio and turn length and in student talk were used as indicators for understanding the language learning opportunities in these classes. Inspirations can be taken from the work in language classes to understand the language learning opportunities in EMI classes.

To my knowledge, in most of the studies exploring classroom interaction in EMI/CLIL classes, the teachers were all bilingual teachers. One could ask if the classroom interaction with monolingual EMI teachers would also follow the same pattern, or the monolingual EMI teachers would use classroom interaction differently. The possible differences monolingual

EMI teachers may bring to classroom interaction, due to their inability of using students' L1 and their high English proficiency, is elaborated later in Section 2.4 of this chapter.

Apart from the lack of studies on monolingual EMI teachers' classes, among the various lines of work on classroom interaction in EMI/CLIL contexts, what is also lacking is research to make use of the well-developed subject-specific teaching frameworks established in L1 contexts, such as constructivist teaching in sciences, and studies with a design of analyzing large-scale classroom data involving multiple teachers. This formed part of the motivation of this study, where the expertise in L1 science education, including the body of work on the constructivist framework of teaching and Dialogic Teaching, was consulted and a relatively large number of classes were analyzed to understand the classroom interaction behavior in EMI science classes by monolingual teachers in the foreign high schools in China.

Following the elaboration of the overall findings in the existing literature on classroom interaction in EMI/CLIL classes, the discussion now turns to two specific components of classroom interaction, which have been argued to bear significant value for learning – teacher questions and student questions.

2.3.4.2 Teachers' questioning skills

An important component of classroom interaction explored in this study is teachers' use of questions. This topic has been widely researched in L1 science classes, language classes as well as EMI/CLIL classes. As Dillon (1990) argued, classroom discourse is dominated by teacher questions. From a sociocultural perspective, researchers have seen teacher questions as mediational tools to scaffold students' learning within the proximal zone of development (Lightbown, Rand, Ranta, & Spada, 2013).

In L1 science classrooms, ample research has been done on the classification of teacher questions, often with the criteria of the level of cognitive demand questions request from students (Erdogan & Campbell, 2008; Gall, 1970; Watts, Alsop, Gould, & Walsh, 1997). Teacher questions are also considered a key tool to realize constructivist teaching in science

classes (Erdogan & Campbell, 2008). In L2 or foreign language classrooms, teachers' use of questions has also been widely recognised as having crucial impact on the quantity and quality of students' output (Long & Sato, 1983; Mehan, 1979), a key component of interaction that leads to L2 acquisition, as explained in Section 2.3.3. Because of the significant value teacher questions have in the learning of both science and language, it is unsurprising that attention has been given to exploring teachers' use of questions in the EMI and CLIL literature as well.

In the field of EMI, Yip, Coyle, and Tsang's (2007) study in Hong Kong and Baharom & Ying's (2010) study in Malaysia both discovered that teachers in EMI science classes tended to use a high quantity of closed and recall questions with a low cognitive demand and little space for co-constructing complex subject matter with students. Considering the challenges EMI teachers often face to engage higher order thinking from students, Yip conducted a series of studies (e.g. 2001, 2004) in Hong Kong to investigate how teacher questions can be used to promote conceptual change in EMI science classes, a key process for science learning in the constructivist view of teaching science. His (2001) study showed that after completing an in-service teacher training program on using conceptual-change questions, although the teachers were able to use a larger proportion of higher-order questions and conceptual-change questions, the use of these questions did not necessarily elicit higher level thinking from the students. He argued that the reason could be that the questions asked were considerably beyond students' level of understanding. He also reported that although many teachers were able to elicit students' preconceptions, many failed to build onto this and ask further questions to lead students to resolve the inconsistencies between their preconceptions and the new concepts. Instead, the teachers were found to usually give the right answers to students immediately.

Similarly, in the CLIL contexts in Europe, teachers' use of questions has also drawn attention. Dalton-Puffer (2007) proposed a framework which consists of five types of questions used by CLIL teachers, including questions for facts, questions for explanations, questions for reasons, questions for opinions, metacognitive questions. Observation of CLIL teachers' use of questions in classrooms also revealed limited use of higher-order thinking questions, such as divergent questions (Menegale, 2011), but a strong presence of recall questions (Schuitemaker-King, 2012). Thus, a similar difficulty for teachers to use higher-order thinking questions also emerged in the CLIL context.

Again, all the EMI & CLIL studies described above featured bilingual teachers. The limited English proficiency level of bilingual EMI teachers has frequently been discussed as one reason for their frequent use of yes/no questions, less cognitively demanding questions, or a lack of use of questions to open up discussion with students (Sopia, et al., 2010; Tan, 2011; Yip et al., 2007). However, one study that particularly explored EMI teachers' use of a wide range of higher order thinking questions is Chin's (2007) study, which is described below.

A rather detailed and elaborate framework of constructivist teacher questions in science classes was developed in Chin's (2007) study, which performed an analysis on 36 video-recorded Grade 7 science lessons by six teachers from four schools in Singapore. Guided by social constructivism, how teacher questions led students' thinking was viewed within the teacher-student dialogues they were situated in, evidenced by students' output and how teachers' follow-up questions were built upon students' answers. Thus, these constructivist questioning approaches were seen as discursive strategies to direct classroom interaction, rather than individual acts. Based on the types of thinking that were encouraged in students, four domains of constructivist questioning approaches with 12 individual approaches were proposed. These four domains are: *Socratic questioning, verbal jigsaw, semantic tapestry, focusing* and *framing.* This framework allows fine-grained analysis of how science teachers use questions to direct classroom discourse to scaffold students' productive thinking. More detailed explanation of this framework is in Chapter 3 Methodology.

While the studies on teacher questions in EMI/CLIL contexts also almost all featured bilingual teachers, whose English proficiency was argued to be one reason for their tendency of using closed and lower-order thinking questions, one could ask whether monolingual EMI teachers with a high level of English proficiency would use questions differently.

2.3.4.3 Student questions

Compared to the vast body of literature on teachers' questions, there are significantly fewer studies exploring student questions in both L1 and L2 contexts. One reason for this, as Dillon (1990) explained, is that students usually do not ask many questions in classrooms. The scarcity of student questions has been identified in studies across different settings and educational levels, e.g. primary school classrooms in the UK (Elstgeest, 1985), secondary school classrooms in the US (Carlsen, 1991), and graduate-level classrooms (Commeyras, 1995; Dillon, 1990; Graesser & McMahen, 1993; Graesser & Person, 1994; West & Pearson, 1994).

Although student questions are uncommon in many educational settings, student active inquiries are considered a crucial component for a constructivist classroom, as elaborated earlier in Section 2.3.2. In addition, empirical evidence has also demonstrated that student questions are beneficial to students' development of conceptual understanding. For example, Harper, Etkina and Lin (2003) found that there is a positive association between asking higher order thinking questions and students' scores on a conceptual performance test. Other studies have elaborated the ways student questions could facilitate the teaching and learning process, particularly through the perspective of constructivism. For example, Chin & Osborne's (2010) and Ciardiello's (1998) work found that student questions could reflect the inconsistency and mismatch between their existing understanding and the science knowledge. Watts et al. (1997) also argued that students asking questions could be the first step in inducing conceptual change, which is at the core of the constructivist idea.

Further to the role of student questions in constructivist teaching, studies have also explored the classification of student questions and how different types of student questions influence learning. For example, Chin (2004) proposed that higher level thinking questions from students can be particularly effective in promoting productive thinking and conceptual talk that are relevant to complex science concepts. Watts et al. (1997) also specifically examined how different types of student questions illuminate the different stages in conceptual change, including consolidation questions, exploration questions and elaboration questions.

In the field of EMI, however, the existing work exploring student questions is remarkably limited. As compared to the work on teacher questions, effort is rare, either theoretically or empirically, to explore student questions in EMI classes and how they impact subject content learning and language learning. The investigation of student questions is another component of the exploration of classroom interaction in this study.

2.3.4.4 Explicit teaching of language and the language of science

It is widely discussed in the EMI literature that students encounter a variety of language difficulties in learning complex subject matter through an L2 (Belhiah et al., 2013; Joe & Lee, 2013; Wu, 2006). The same issue with language has also been frequently discussed in CLIL and other L2 content contexts (Fortune, Tedick, & Walker, 2008; Kovacs, 2009). This section focuses on the arguments in the existing literature on the need for explicit instruction on language in L2 content classes and, as this study explores the context of science classes, the language challenges EMI science students have been found to experience. In the end, this section also highlights the lack of research so far on exploring the explicit instruction on language in EMI classes.

2.3.4.4.1 The need of explicit teaching of language

While EMI/CLIL classes are argued to provide ample opportunities for incidental learning of the L2 through communication of content ideas, as explained in Section 2.3.3, a number of scholars have increasingly called for the need to explicitly address students' L2 needs in subject lessons (Lyster, 2007; Sherer et al., 2009). In fact, in the literature of French immersion programs, many argue that the lack of explicit attention to the teaching of the L2 in subject lessons is a major reason for French immersion students' less than satisfactory level of L2 proficiency (Fortune et al., 2008; Hoare, 2003; Lyster & Ranta, 1997)Similarly, scholars in the immersion programs in the US contexts also reported that immersion students experience problems with grammatical accuracy in their productive language skills (De Oliveira & Schleppegrell, 2015). In fact, even in communicative language classrooms, evidence has been provided for an integration of form-focused activities (Long & Robinson, 1998; Norris & Ortega, 2000; Spada & Tomita, 2010). If accuracy in students' production of L2 is a

pedagogical goal in EMI, then these findings from other bilingual programs indicate a need for explicit L2 instruction to enhance the accuracy of students' use of English in the EMI contexts, too.

Motivated by the findings above, a number of strategies have also been proposed by various scholars for enhancing language-focused instruction in L2 content classes. These strategies include providing corrective feedback and forms-focused tasks, careful lesson planning for the learning of language structures, modelling complex language structures in classes and so on (Barwell, 2005; Genesee, 2006; Lyster, 2007). These ideas are also elaborated in Lyster's (2007) counter-balanced approach in immersion classes, calling for a combination of content-focused instruction and form-focused instruction in L2 content classes.

The need of language support has also been frequently called for in EMI studies, where students have been found to experience various linguistic challenges. For example, Evans and Morrison's (2011) longitudinal studies, which examined students' transition from CMI (Chinese medium instruction) secondary school education to EMI university education in Hong Kong, reported academic writing in English being the biggest challenge for students. Other challenges identified in this study include comprehension of lectures and reading materials and expressing views accurately in speaking. Khan's (2013) study in Pakistan and Kang & Park's (2005) study in South Korea also discovered EMI students' lack of confidence to speak up in classrooms, their difficulties with comprehension of the lecturers and texts, and academic writing. These linguistic challenges indicate a strong need for language support for EMI students. Together with the evidence from other L2 content classes and communicative language classes, the reliance on incidental learning of the L2 through communication in EMI classes seems not enough to facilitate students' L2 development and help them overcome the language challenges. In EMI classes, language-focused instruction also is necessary in promoting students' L2 learning.

2.3.4.4.2 The language of science

In EMI science classes, which is the context of this study, the features of the language of science also add to the need of explicit language instruction. While the distinctive register of the language of science presents challenges to both L1 and L2 students, the challenges the L2 students experience are particularly significant. The discussion here first focuses on introducing the features of the language of science, and then moves to highlight the difficulties that have been reported for EMI science students.

2.3.4.4.2.1 Features of the language of science

The language of science is specialized through technical terms and specific patterns of discourse, such as lexical density, grammatical metaphor, nominalization, and syntactic discontinuity (Fang, 2005; Halliday, 1993; Martin, 1991). Literature in science education has widely discussed the distinctive features of the language of science and the possible difficulties that could be caused by it. The discussion below first illustrates the features of the language of science in terms of vocabulary and grammar, and then highlight the challenges they could cause for EMI students in particular.

Wellington and Osborne (2001) developed a taxonomy of words of science, which classifies scientific words into three levels - naming words, process words and concept words. As Wellington and Osborne stressed, concept words are the largest one among words in science and is the most difficult for students. Concept words represent precise science concepts which are probably new to students, and yet those words may also have a different meaning in daily life, such as *energy*, *work* (Halliday, 1998; Halliday & Martin, 1993; Lemke, 1990). The mastery of these words includes distinguishing the two meanings and understanding the scientific concepts behind. When the concepts are abstract, e.g., *gravity*, the difficulty of understanding those words increases significantly and they are a major cause of problems in science education (Swain, Kinnear, & Linda, 2015; Wellington & Osborne, 2001).

As the science concepts are rarely used alone but situated in a sentence, or a context due to the complex relationships among the scientific concepts (i.e. causal relationship), it is also crucial to teach the language that expresses relationships among scientific concepts, i.e., the thematic

patterns in Lemke's terms (Lemke, 1990). The ample use of nominalization (e.g. *acceleration*) and passive voice are also examples of the prominent features of science discourse, highlighted by systemic functional linguists (Halliday, 1993). As the language use in science possesses distinctive features from everyday English, challenges are presented to both L1 and L2 students (Halliday, 1993, 1998).

2.3.4.4.2.2 The difficulties EMI science students experience

While the language of science poses difficulties to both L1 and L2 students, for L2 students, the difficulty of mastering the language of science is argued to be more significant (Crandall, 1987). EMI studies have reported that students, unsurprisingly, have problems with technical vocabulary (Yip et al., 2003). In Probyn's (2006) work on EMI education in South Africa, she reported that the majority of students have difficulties both in comprehending the questions in English and expressing their ideas in open-ended questions in English. Apart from learning the technical words, they may also lack some of the more basic linguistic resources, which native speakers already possess, such as general vocabulary and connectives to express relationships in their communication of science ideas (Clark, 1997; Prophet & Towse, 1999).

While it is acknowledged that EMI students experience problems with the technical vocabulary, i.e., science specific terms, it is of empirical interest to explore whether EMI students' problems with technical vocabulary are caused by the form and surface meaning of the actual technical word, or by the language contained in the explanation of the technical word, which could be non-technical language normally known to L1 students. It is thus one of the goals in the exploration of classroom interaction in this study to examine the kind of vocabulary that are explained in the EMI science classes. While the boundaries between technical and non-technical lexical items are not watertight, technical vocabulary are defined as the vocabulary that is likely to be listed in a technical dictionary or the glossaries of a textbook in a specific academic subject, such as *photosynthesis, glucose, molecule*. Non-technical vocabulary is defined as such that are unlikely to be found in the glossaries of a science subject textbook. They include both the general academic vocabulary, which are listed in Coxhead's (2000) academic words, e.g., *compile*, and the everyday vocabulary, e.g., *truck*. It is speculated that in L1 classes, a secondary school student does not need the teacher to

explain the meaning of '*compile*' or '*truck*', but for EMI students, an explanation might be needed.

Another motivation of this study to explore the explicit teaching of language is the increased demand of academic literacy at the secondary school level. This is reflected in the increased complexity of the grammar structures in the texts students encounter. As De Oliveira & Schleppegrell (2015) explains, at the secondary school level, the grammatical forms students encounter tend to have clause structures, complex noun phrases, and nominalization where information is densely packed, as well as the grammar devices that maintain cohesion in texts, such as reference. Thus, the change of the grammatical features of the texts at the secondary school level has also been recognized as a key concern for L2 students, and a need for incorporating explicit teaching of the academic grammatical features in subject classes has also been called for (De Oliveira & Schleppegrell, 2015; Schleppergrell et al., 2004). This is also an interest of this study to explore the extent of explicit instruction on grammar in the classroom interaction of the EMI science classes in this study.

2.3.4.4.3 A lack of research on explicit instruction on language in EMI classes

While various linguistics challenges, including in terms of vocabulary and grammar, are identified for EMI science students at the secondary school level, there is a lack of research to explore the explicit instruction on language in EMI classes. Among the few studies on this topic, limited focus on form has also been reported in Pérez-Vidal's (2007) study in CLIL classes in Spain, Lo's (2010) work with EMI teachers in Hong Kong, and Llinares & Lyster (2014) study in CLIL classes where it was found that teachers' feedback to student output also lacked explicit correction and the use of metalingusitic cues. At the university level, Basturkmen and Shackleford (2015) found few language-related episodes in the interaction of university accounting classrooms and that these were mostly in relation to technical vocabulary. By analysing a corpus of lectures in EMI science subjects, Costa (2012) also found a very limited number of, what she refers to as, focus-on-form episodes. Moreover, in some of these focus-on-form episodes the practice of codeswitching was present because these were bilingual (Italian/English) EMI teachers, unlike the monolingual teachers in this study. Thus,

in this study, featuring monolingual teachers, it is interesting to explore the extent to which explicit instruction in language occur and the language aspects addressed.

In summary, this section justifies the importance of exploring classroom interaction, reviews the literature on classroom interaction in EMI and other L2 content classes, and discusses the importance of providing explicit instruction on language in EMI science classes at the secondary school level. Most of the studies so far feature bilingual teachers and few studies have examined monolingual EMI teachers' classes. This leads to the discussion below on the possible differences monolingual teachers may bring to classroom interaction and why it is significant to examine EMI classes taught by monolingual teachers.

2.4 Monolingual vs Bilingual EMI Teachers

As mentioned at the beginning of this chapter, one distinctive feature of the EMI scenario in this study, i.e., the foreign high school programs in China, lies in the monolingual teachers who cannot use their students' L1 to any degree of functionality in their teaching. With reference to the literature on classroom interaction discussed above, this section provides a more detailed discussion on the significance of researching about monolingual EMI teachers. Comparing to bilingual EMI teachers, the differences monolingual EMI teachers may bring to classroom interaction are discussed in two aspects, the teachers' use of students' L1 and the teachers' proficiency of English. In the end of this section, the relevant discussion in the field of ESL/EFL on native speaking (NS) and nonnative speaking (NNS) teachers is also presented.

2.4.1 Monolingual vs bilingual EMI teachers: the use of students' L1

Ample empirical evidence has been gathered in the literature on bilingual EMI teachers' use of L1 in various ways to attempt to facilitate content teaching and language teaching.

The common functions of teachers' L1 use include explaining difficult vocabulary (Costa, 2012; Lo, 2010; Maxwell-reid, 2017), describing daily life experience in relation to the subject content and providing emphasis (Gierlinger, 2015; Lasagabaster, 2017; Li, 2015; Lin, 1996; Lin & Wu, 2014; Probyn et al., 2002), performing administrative procedures and classroom management (Lin, 1996). Teachers' L1 use has also been observed for extending teacher-student interaction in EMI and CLIL classrooms, such as scaffolding students' output in L1 and phrasing it in L2 (Lin & Wu, 2014; Urmeneta & Walsh, 2017), and paraphrasing a question when receiving no response from students (Then & Ting, 2011). While codeswitching clearly exists in EMI/CLIL classrooms, the amount of L1 use in teacher talk seems to vary considerably from context to context. In Wannagat's (2008) comparison study between CLIL history classes in Germany and EMI history classes in Hong Kong both at the secondary school level, it was reported that 42.6% of the EMI teachers' talk in Hong Kong was in L1 whereas only 0.3% of the CLIL teachers' talk was in L1 in Germany, demonstrating the vast variation regarding the proportion of teachers' L1 use in in different contexts.

The conceptual debate over L1 use has seen arguments both approving of it and disapproving it. Among the views against L1 use, some scholars argued that the use of L1 contradicts the Interaction Hypothesis by reducing students' exposure to maximal L2 input (Macaro, 2005). Others have also explained that L1 could become an easy way out for solving communication problems rather than negotiation of meaning in the L2 (Long, 1996). As Macaro (2018) specified, unprincipled use of L1 undermines the learners' risk-taking in experimenting the use of L2 in the communication of subject knowledge. Thus, the very theoretical basis of how EMI education is believed to be effective in promoting L2 learning, i.e., ample exposure of and meaningful communication in the L2, is compromised.

Arguments supporting L1 use, however, have also found support from the Interaction Hypothesis. Macaro (2005) suggested that the time available for students to produce L2 output can be reduced because of teachers' lengthy input modifications and the negotiation of all the communication breakdowns. The strategic use of L1 can alleviate this problem. In addition, teachers' understanding of students' L1 and the difficulties L1 may cause in students' L2 learning also render it possible for teachers to provide pre-modified input to ensure comprehensibility.

Apart from the theoretical basis of the Interaction Hypothesis, the benefits of L1 use can also find explanations from Vygotskian sociocultural theory, a key theoretical framework for the exploration of interaction in this study, as explained in Section 2.3.1. Vygotsky (1978) argued learners' inner voice and private speech play an integral role in their cognitive activities. As Cohen's (1998) study shows, even advanced L2 learners prefer L1 as the language of thought. This perspective is particularly relevant in the EMI contexts where cognitive activities about complicated content knowledge are likely to take place and the language of thought students use, even for advanced learners, could well be their L1.

In the field of ESL/EFL, empirical evidence has also been gathered to explore language teachers' L1 use, with the recent arguments more in favour of strategic L1 use. It has been shown that ESL teachers' understanding of students' L1 can allow them to provide the English equivalents when necessary, which is argued to be beneficial for students' L2 learning (Macaro, Nakatani, Hayashi, & Khabbazbashi, 2014). Bilingual teachers are also argued to have the advantage of choosing strategically how and when to use each language in giving explanations, such as providing definitions, paraphrasing, and giving examples (Macaro, Guo, Chen and Tian, 2009). L1 translations are also found to be beneficial for lexical processing where learners can map new L2 words onto L1 (Tian & Macaro, 2012; Zhao & Macaro, 2016).

With the debate on L1 use moving towards the recognition of the possible benefits L1 and the understanding of strategic L1 use in ESL/EFL and EMI classes, the monolingual teachers in this study cannot use it themselves to fulfil any pedagogical functionality. However, the monolingual teachers have the advantage to provide sufficient input and input modifications in L2 and ensure L1 is not used as an easy way out when communication breakdowns happen and negotiation of meaning through L2 is needed.

2.4.2 Monolingual vs bilingual EMI teachers: English proficiency

Apart from the ability to use students' L1, the high level of English proficiency is another characteristic of monolingual teachers that could possibly make an impact on classroom interaction, with implications for language learning and subject content learning. Due to the increased complexity of the subject matter at the secondary school level, the demand for EMI teachers' English proficiency to master the use of vocabulary, grammar and the genre of their subject discourse is also likely to be high (Macaro, 2018). In the existing EMI literature featuring bilingual teachers, a lack of English proficiency on the teachers' part has been often reported as a main challenge for successful implementation of EMI. This issue has been identified in the EMI schools in Hong Kong (Lin, 1997; Yip et al., 2003), South Korea (Cho, 2012), Malaysia (Ali, 2013; Tan, 2011), Indonesia (Zacharias, 2013), South Africa (Probyn, 2006), South America (An & Murphy, 2018), Sweden (Lim Falk, 2008; Paulsrud, 2016), Finland (Moate, 2011) and so on. Similarly, at the higher education level, EMI lecturers also often expressed concerns over their lack of English proficiency (Macaro, Curle, Pun, An, & Dearden, 2018). Hu in his (2009) work on EMI in higher education in China also highlighted the limited English proficiency of the bilingual lecturers as one of the major pedaogical obstacles for implementing EMI.

Due to the reported bilingual EMI teachers' unease with English in many EMI contexts, the amount and quality of L2 input students receive in EMI classrooms are argued to be often compromised (Hu, 2009; Yang & Gosling, 2013; Campagna, 2016). This inevitably undermines a key condition for L2 development that EMI classes are believed to be able to create, i.e., the condition of sufficient and accurate L2 input. In addition, in some cases bilingual EMI teachers' limited English proficiency is also perceived to have prohibited extensive interaction with students involving higher order thinking (Sopia, et al., 2010; Tan, 2011; Yip et al., 2007), as also mentioned earlier in Section 2.3.4.1, and led teachers to simplify the content knowledge and reduce the cognitive demand (Qiang, Huang, Siegel, & Trube, 2011; Shen, 2004). Similar issues with bilingual EMI teachers' language proficiency are also discussed in higher education where EMI lecturers themselves reported difficulties in explaining content knoweldge fully and communicating content knowledge clearly in English (Başıbek et al., 2014).

The difficulties discussed above, particularly caused by the bilingual teachers' lack of the English proficiency, place constraints on students' language learning and content learning. The reduced level of cognitive demand and complexity of content knowledge in the classroom talk also means reduced language learning opportunities where complex language structures can be brought out during discussion of complex content ideas. As a result, the pedagogical benefits of EMI are in doubt. In Cho's (2013) study exploring EMI in higher education in South Korea, students regarded EMI as ineffective in delivering course content due to their professor's limited English proficiency. Students' unsatifactory academic performance has also been reported (Lin, 1997; Lo & Lo, 2014), as well as a level of performance in English that is no better than non-EMI counterparts when the teachers' satisfactory English proficiency is found to be a key missing factor (Lei & Hu, 2014).

The often use of students' L1 by bilingual EMI teachers, as discussed in the section above, have also been found to be sometimes associated with the teachers' lack of English proficiency. In some studies, teachers were described to switch to L1 due to their struggle with using English to teach complex subject content matter (Joe & Lee, 2013; Lin, 1997; Tan, 2011). In these cases, the switch to L1 is not a pedagogically sound decision but a result of the teachers' lack of sufficient linguistic resources in L2. Thus, the use of L1 in these circumstances is an easy way out and compromises the valuable opportunities for providing L2 exposure with sophisticated linguistic structures, eliciting student output in L2, and the possible incidents of negotiation of meaning, which are the key mechanisms of how interaction promotes L2 development (Krashen, 1982; Long, 1996).

With all the research findings above in mind, the monolingual teacher population in this study, who possess a rather high level of English proficiency, means that the teachers' own English proficiency is unlikely to put restraints on their talk and interaction with the students. Thus, it is interesting to observe without this restraint whether the classroom interaction would be different.

It also needs to be acknowledged that students' English proficiency has also been frequently described as another factor that inhibits students from fully benefitting from EMI education

(Cho, 2012; Gu & Dong, 2005; Lei & Hu, 2014; Lo & Macaro, 2012), as also elaborated in Section 2.3.4.4.2.2 earlier. However, unlike the monolingual teacher population in this study, the English proficiency level of the target student population does not differ significantly from the students in the existing EMI literature. Although there is no standardized English proficiency test to evidence the students' English proficiency in this study, based on the fieldwork, it was clear that the students also had struggles with English, which are shown in the results chapters of this thesis.

In summary, while English proficiency is a challenge many bilingual EMI teachers face, the monolingual teachers in this study possess a high level of English proficiency, thus pre-empting the language issue being a reason for reducing the use of classroom interaction with their students. It is interesting to see, when the teachers' English proficiency is high, whether the classroom interaction would be different from the pattern described in the previous literature with bilingual EMI teachers.

2.4.3 NS vs NNS teachers in language classrooms

Although the discussion of monolingual teacher and bilingual teachers is rare in the EMI literature, in the field of ESL/EFL, there has been a long debate about native speaking (NS) teachers and nonnative speaking (NNS) teachers. The monolingual EMI teachers in this study could be compared to the NS language teachers and the bilingual EMI teachers in the literature could be seen as resembling the NNS language teachers.

Research has shown that both NS and NNS English language teachers possess their respective advantages and disadvantages (Cheung, 2002; Cook, 2005; Liang, 2002; Mahboob, 2003). The NS teachers are considered stronger at oral skills and authentic pronunciation and are considered possessing a more skilful mastery of a wide range of vocabulary (Cook, 1999; Mahboob, 2003). They are also commented as having high awareness of the native English-speaking culture while the NNS teachers are considered to possess good literacy skills (Cook,

1999; Mahboob, 2003). On the other hand, the NNS teachers have an advantage in their knowledge about the English language and linguistic awareness, such as the grammar rules. NNS teachers are also able to make comparisons between L1 and L2 and are commented as more understanding to students' needs due to their own experience as an English language learner. This leads to their stronger competence in predicting students' difficulties. Other merits of NNS teachers include that they are a successful model of an L2 user to students, are able to introduce effective language learning strategies they themselves used, and make comparisons with the students' L1 as a tool to explain certain language features in English (Benke & Medgyes, 2005; Braine, 2005).

These arguments in the field of ESL/EFL also have implications for the EMI context. A bilingual EMI teacher could have the advantages identified for NNS teachers, including the ability of resort to students' L1 to explain the target language, understanding the students' language struggles in learning content through an L2, possessing more linguistic awareness about English and so on. A monolingual EMI teacher, similarly, can also possess the characteristics identified for NS language teachers, including stronger oral skills and a wider vocabulary repertoire, while being at a disadvantageous place in the areas an NNS language teacher is believed to have strengths in.

One rare study that explored the teachers' and students' views of monolingual EMI and bilingual EMI teachers is Toth's (2018) study, situated in a primary school in Sweden where foreign non-Swedish speaking EMI teachers are hired. While there is little exploration of the comparison between monolingual and bilingual EMI teachers in the literature, the finding from Toth's study shows that some teachers and students preferred monolingual teachers, who were seen as able to provide exposure of authentic English to the students, and others preferred bilingual teachers, who were seen as having the advantage of explaining subject matters in Swedish.

Considering all the discussion above in the previous literature on bilingual EMI teachers' use of students' L1 and their English proficiency level, the debate of NS vs NNS language teachers, and the limited evidence so far on comparing monolingual EMI and bilingual EMI teachers,

it is worth asking the question if monolingual EMI teachers may use classroom interaction differently.

2.5 Understanding teachers: professional background and belief

Apart from the exploration of classroom interaction, this study also aims to understand the monolingual EMI teachers' professional background, and the beliefs held by the monolingual EMI teachers and their Chinese students about effective teaching of science and English in the foreign high school programs in China. Previous studies have shown a teacher's professional background and beliefs have significant influence on teachers' practices.

2.5.1 Teachers' professional background

Research has identified a teacher's past teaching experience and their professional training and academic background as crucial factors in the formation of their teaching beliefs and practice. Such observations have been found in ESL/EFL contexts, (Ellis, 2006), L1 subject contexts (Freeman, 1991; Mansour, 2009), and EMI contexts (Lo, 2017). Apart from teachers' training background in science education, their training in language education is also explored in this study because of the concern for developing students' English in EMI classes. Previous studies suggest that many subject teachers in bilingual programs do not have specific training in language teaching or EMI/CLIL pedagogy (Barwell, 2005; Fortune et al., 2008). It is one pursuit of this study to discover if this is also the case with the monolingual teachers in the foreign high school programs in China.

Apart from the training background on language teaching, a teacher's own learning experience of an L2 is also argued to be influential of their teaching behaviours in language classes (Ellis, 2006). For the monolingual teachers in this study, acquisition of English is likely to have taken place in their early childhood, which is largely unavailable for reflection. In addition, L1 acquisition is also considered to be of a very different nature from learning an L2 in

instructional contexts (Hoff, 2014). However, if the monolingual teachers have learned other languages through their schooling, they have had similar experiences as their Chinese students who learn English as an L2 in classrooms. This experience of learning an L2 themselves, despite a different L2 from the students', is likely to be a source of insights which might contribute to their beliefs and practice of language teaching (Ellis, 2006; Woods, 1996).

2.5.2 Conceptualization of teacher beliefs

Teacher beliefs are an important and widely researched construct in teacher education. They guide teachers' lesson planning, pedagogical decisions in the classrooms, and influence the quality of teaching (Kagan, 1992; Kane, Sandretto, & Heath, 2015; Kang & Wallace, 2005). Teacher beliefs are important to explore if the teaching and learning processes are to be improved.

Teacher beliefs about teaching have been argued to be the result of many factors. Richardson (1996) argued personal experience, experience with classroom instruction, and experience with formal knowledge all form important factors in influencing a teacher's belief. Pajares (1992) also argued that teacher beliefs about teaching are formulated through many years of formal schooling and that they may be difficult to alter. Through understanding the factors that influence the formation of beliefs, it can be seen that the construct of beliefs not only includes a teacher's knowledge about teaching, but also is highly personal with strong affective and evaluative components to it, and has a level of stability (Haney & McArthur, 2002). A teacher's beliefs about teaching reflects how they think teaching should be conducted in an ideal situation, which may differ from reality.

In this study, the exploration of the foreign monolingual EMI teachers' beliefs concerns their beliefs about teaching science and English in EMI science classes. The definition of teacher beliefs proposed in Kagan's (1992) article, which was later used in Mansour's (2013) study on exploring science teacher beliefs about effective science teaching and comparing them to their practice in classrooms, is considered appropriate for the purpose of this study. The

definition is '*the highly personal ways in which a teacher understands classrooms, students, the nature of learning and the teacher's role in the classroom'* (Kagan, 1992, p.423). This definition captures the main dimensions of the exploration of beliefs in this study, where the monolingual EMI teachers' understanding of the EMI science classrooms, their Chinese students (e.g., the difficult language areas for their students) and their role as a language teacher in EMI science classes all play important roles. These elements will be explained later in Section 2.5.3 and Section 2.5.4.

To provide an overview, the construct of teacher beliefs in this study entails two major domains: 1) beliefs about science teaching; 2). beliefs about language teaching. This is due to the duality of EMI education, i.e., the teaching of subject content and language. Thus, the exploration of teacher beliefs in this study aims to discover what the teachers believe is effective teaching of science and English in EMI science classes. In this investigation, the role of interaction is emphasized. The specific components of these two categories, together with the theoretical underpinnings, are elaborated below.

2.5.3 Teacher beliefs about teaching science: traditional and constructivist view

The first domain in the construct of teacher beliefs in this study is teacher beliefs about effective teaching of science. In the literature of science education, L1 science teacher beliefs about effective teaching of science has been heavily researched (Gallagher, 1991; Hashweh, 1996a; King, 1991; Mansour, 2009, 2013; Prawat, 1992). In most of the recent studies, the discussion of science teacher beliefs are often described along the continuum between the transmissionary view and constructivist view of teaching (Hashweh, 1996a; Kang & Wallace, 2005; Mansour, 2009; Sampson et al., 2007). The difference between the two is explained in Section 2.3.2 earlier.

As explained earlier, the construct of teacher beliefs represents teachers' personal ideals of what they believe, and they could be different from reality. The difficulties of translating beliefs into practice in fact have been frequently explored in L1 science classes, and various

contextual factors have been argued to mediate this relationship. For instance, Mansour's (2013) study focused on 10 secondary school science teachers in Egypt with diverse beliefs about science teaching, with each of them having been observed for three to four lessons. The teacher beliefs and classroom practices were grouped into three categories: traditional, mixed and constructivist view. The results suggest that many teacher beliefs were characterized by constructivist ideas, but their practice were more traditional. As discussed by Mansour and a number of other scholars, e.g., Abd-El-Khalick & Lederman (2000) and Brown & Redmond (2008), the inconsistencies between science teacher beliefs and their practices could often be due to the constraints imposed by contextual factors, such as teachers' professional-academic background, institutional and curriculum constraints, culture of the school and the society, classroom settings and students' behaviour, teachers' and students' past experience, time, resources and so on. Kang and Wallace's (2005) study showed that even experienced secondary school science teachers possessing constructivist beliefs do not always have constructivist practice due to the constraints of contextual factors. Thus, while teacher beliefs have an impact on their teaching behaviour, it also needs to be acknowledged that how teacher beliefs transfer into practice is dependent on or restricted by the context (Fang, 1996; Kane et al., 2015; Mansour, 2013).

As this study involves teachers and students from different countries, the factor of teachers' and students' cultural background is also relevant, although this dimension is not a primary focus of this study. Alexander's (2000) work, which forms an important basis for the Dialogic Teaching approach, as introduced earlier, examined the teacher talk in primary schools in England, US, France, India and Russia. He discovered that while the use of extensive dialogues and other behaviour promoted in Dialogic Teaching are associated with higher academic attainment across these countries, the implicit ground rules of talk in classrooms varied across different cultures. This suggests that the foreign teachers and the Chinese students in this study may have different beliefs about the implicit rules about how teachers and students should talk in classrooms. This also justifies the necessity of exploring both the teachers' and students' beliefs about the role of classroom interaction in this study.

As can be seen in the discussion above, most of the existing studies investigating science teacher beliefs are situated in the contexts where the medium of instruction is the students' L1.

Very few studies in the EMI contexts have made references with this body of research and explored the EMI science teacher beliefs about effective science teaching, particularly regarding the role of interaction. Thus, one of the aims of this study is to apply this area of expertise in the EMI contexts.

2.5.4 Teacher beliefs about teaching language: teacher language awareness, teacher identify and the use of interaction

Apart from the domain of science teaching, the other dimension of teacher beliefs explored in this study concerns the teaching of English in EMI science classes. This dimension entails several components: 1). teachers' own proficiency of the language of science in English; 2). teachers' knowledge about the features of science in English and the general English language; 3). teachers' understanding of Chinese students' difficulties with the language of science and general English; 4). teachers' perceptions of their role as a language teacher; and 5). teachers' understanding of how interaction promotes L2 learning.

The first three components above came from the concept of teacher language awareness (TLA) developed in the field of ESL/EFL, which will be illustrated in Section 2.5.4.1 below. The fourth component concerns EMI teachers' identity, which is an issue that is widely explored in EMI literature, and will be discussed in Section 2.5.4.2. The last component specifically enquires about EMI teachers' understanding of the role of interaction for L2 development, corresponding to the focus on classroom interaction in this study.

The sequence of these components follows the logic of first consulting the expertise of TLA, which has been long established in ESL/EFL research, and then moves onto explicitly enquiring if the EMI teachers see language teaching their responsibility. Following the issue of if they see themselves as language teachers, how they understand L2 pedagogy, i.e., the use of interaction in this case, is investigated.

2.5.4.1 EMI subject teachers' language awareness

Teacher language awareness (TLA) is an extensively researched concept in the field of ESL/EFL and it is argued to be crucial in effective language teaching (Andrews, 2007). As facilitating students' L2 development is also an integral task in EMI classrooms, the concept of TLA is applied in this EMI context. In Andrews's series of influential works (2001, 2003, 2007), TLA is conceptualized as entailing the following three components: 1).teachers' proficiency of the language; 2).teachers' knowledge about the language (e.g., grammar); 3).teachers' understanding of their students' needs. As the context of this study is EMI science classes, the special discourse of the language of science also needs to be considered. Thus, the concept of TLA outlined in Andrews's work is expanded in this study to include the language of science in English, in addition to general English.

The first component of TLA, the teachers' own proficiency of the target language, is adjusted in this study to include only the teachers' proficiency of the language of science. The reason for not investigating the teachers' proficiency of general English is that the monolingual teacher population in this study are foreign teachers, typically from majority English-speaking countries. Thus, they are believed to possess a high level of English proficiency, which is a key characteristic associated with them, as compared to many bilingual EMI teachers. The sample teachers' English proficiency level in this study was also confirmed in the teacher background questionnaire by asking if English is the teachers' most proficient language. Details can be found in Chapter 3 Methodology. Thus, the investigation of the monolingual teachers' proficiency of general English is deemed unnecessary. What is important to include is teachers' proficiency of the language of science. The second and third components of TLA, i.e., teachers' knowledge about the target language and teacher's understanding of students' needs, include both the language of science and general English. This is because that the fact a teacher is from an English-speaking country does not guarantee that the teacher has good explicit knowledge about how the English language works or knowledge about their students' language needs.

The importance of TLA in EMI classes can also be explained by Interaction Hypothesis (Long, 1996). Teachers need to possess clear and accurate understanding of their students' needs to provide modified input that is comprehensible to students and slightly above students' current linguistic level. Teacher also need to be proficient in the target language to provide accurate input. Sufficient knowledge about English is also necessary to provide targeted feedback to students' output, such as metalinguistic clues, to explain language rules to students.

In the existing EMI literature, few studies have investigated all three components of TLA. A study that specifically explored EMI teachers' language awareness is Hoare's (2003) PhD thesis, situated in EMI secondary schools in Hong Kong. In Hoare's investigation of six EMI science teachers' language awareness and teaching practice, he defined teachers' language awareness as the awareness of the language of science and the awareness of students' need for language support. To compare it with the concept of TLA adopted in this study, only parts of the second and third components of TLA were explored in Hoare's (2003) thesis, and there was not a clear specification of including both the language of science and general English. Thus, this study aims to explore the teacher's language awareness in a rather comprehensive manner.

2.5.4.2 EMI teachers' identity as a language teacher

The fourth component of the language dimension of the teacher beliefs explored in this study is the degree of EMI teachers' identification of themselves as a language teacher. This has been a frequently researched topic in the EMI literature, which could be seen as a response to the need of integrating language teaching into content teaching in EMI classes (Lo, 2017).

Despite the wide recognition of the importance of explicit language teaching in EMI, CLIL and immersion classes, the general findings so far show that the subject teachers in these programs did not seem to accept their identity as a language teacher (Fortune et al., 2008; Hoare, 2003; Walker & Tedick, 2000). For example, Salomone's (1992) study of six teachers in a French immersion school in the US showed that the teachers saw their students' L2

attainment as a secondary concern after their subject learning. Similarly, Lo's (2014) study showed that many EMI science teachers in Hong Kong considered the teaching of academic English language not their responsibility but English teachers' and their teaching also echoed their beliefs. Walker's (2011) study, also situated in Hong Kong, found that science teachers showed a low level of awareness of integrating the teaching of the discourse features of science texts into lesson planning and actual teaching.

These studies above all feature bilingual teachers. It could be speculated that with monolingual teachers' own high English proficiency level, they may be more confident with taking on the role of a language teacher in their subject classes. It could also be possible that without knowledge about the students' L1, the monolingual teachers may not feel well-quipped with the teaching of English to Chinese students. The exploration of monolingual EMI teachers' degree of identification as a language teacher in this study is another area of contribution this study can make.

2.5.4.3 EMI teacher beliefs about interaction for L2 learning

Following the issue of whether monolingual teachers see themselves as language teachers, the investigation of teacher beliefs about language teaching in EMI classes proceeds to what they believe is effective teaching of English in their EMI science classes, in relation to classroom interaction. The theoretical underpinning of the significance of interaction for L2 development is elaborated in Section 2.3.3 earlier.

In the existing literature, EMI teachers' beliefs about L2 pedagogy are rarely touched upon. However, the underlying rationale of the effectiveness of EMI to promote L2 learning is largely built upon the language learning opportunities created through interaction in content classes, as explained earlier in Section 2.3.3. Thus, the exploration of what EMI teachers believe about the role interaction for L2 development has particularly significant value if the integration of language development is aimed to be promoted in EMI classes. The lack of research in this area has also been identified by Cammarata & Tedick (2012) and Hoare (2003),

where they highlighted that the exploration of EMI and CLIL teachers' awareness of L2 specific pedagogy is urgently needed.

As Macaro (2018) summarized, most of the studies investigating classroom interaction in EMI and CLIL rarely triangulated their exploration of classroom interaction with understanding '*teacher beliefs about their role as teachers and the identity they currently hold and may wish to reserve'* (p.229). The exploration of teacher beliefs about teaching science and English in EMI science classes can provide rich triangulation of the investigation of classroom interaction, where the teachers' beliefs about key pedagogical issues (i.e., teaching of science and English) and the identity they hold (i.e., the identity of a language teacher) could provide possibly helpful explanations of classroom interaction.

2.6 Understanding student beliefs

Apart from teacher beliefs, student beliefs are another key area of interest of this study. The construct of student beliefs explored in this study also entails the same components as the ones in the teachers' beliefs, thus including two categories -1) beliefs about science teaching; 2) beliefs about language teaching in EMI science classes.

In the existing EMI literature, most studies exploring students' voices in the EMI contexts are centred around the issues of attitudes of EMI, perceived benefits and challenges, experiences with EMI and so on (e.g. Hunt, 2011; Pladevall-Ballester, 2014; Lo & Macaro, 2012; Probyn, 2005; Tatzl, 2011; Yeh, 2014). Such studies often feature large quantitative data collected through questionnaires, sometimes complemented with qualitative data from student interviews. Both positive and negative attitudes of EMI have been reported. For example, in Hong Kong a clear desire for EMI education at the secondary school level have been identified among students as well as parents (Chan, 2014; Tung, Lam, & Tsang, 1997). However, negative attitudes of EMI have also been captured, often due to the difficulties EMI imposes on the subject content learning, such as in Tarhan's (2003) study situated in secondary schools in Turkey and in Cho's (2012) study with undergraduate and postgraduate students in South

Korea. The challenges with content learning in EMI have even been found in contexts where a higher level of English proficiency is believed to be in place, such as Norway (Hellekjaer, 2010).

While many studies have been conducted on understanding students' attitudes towards EMI and their experiences, few have delved into students' beliefs regarding pedagogical practices in EMI classrooms, i.e., what they believe is effective teaching for subject learning and English learning. However, student beliefs about teaching and learning have been argued to influence their learning processes and their engagement in classrooms (Lasagabaster, 2009; Sylvén, 2013). Scholars in language education have also highlighted that students' beliefs has a major influence on their language learning behaviours in and outside of classroom contexts, and students may lose motivation or question their teachers' practice if their expectations of effective language teaching are not met (Schulz, 1996; Brown, 2009). Thus, understanding students' beliefs is important for the improvement of teaching and student learning. The exploration of student beliefs in this study aims to provide the much needed evidence on what students believe is effective teaching of science and English in EMI science classes.

Parts of the exploration of student beliefs in this study also include their beliefs about EMI teachers' identity as a language teacher and their perceptions of their EMI science teachers' language awareness (TLA). As explained earlier in Section 2.5.4.2, EMI teachers' views on their identity as a language teacher has been frequently researched. However, little is known about the students' views on this issue. Similarly, the students' perceptions of their EMI science teachers' TLA is not often explored to allow comparison with the teachers' own self report of TLA.

2.7 Summary of the significance of this study set against prior research

This study takes an initial attempt to investigate the recently emerging new EMI scenario in China, i.e., the foreign high school programs, from a pedagogical perspective. Guided by the

established frameworks and theories in science education and language education, the significance of this research set against prior research is summarized below.

1. The monolingual teacher population eliminates one commonly reported problem in the existing EMI literature mostly featuring bilingual teachers, i.e., the teachers' unsatisfactory English proficiency, but also means students' L1 is not at their disposal as a pedagogical tool. This creates a rare scenario where the teacher's own English proficiency is unlikely to compromise the use of classroom interaction but L1 is not available to the teacher to help out the interaction.

2. The interdisciplinary approach this study takes is another area of contribution this study could make. References to frameworks well established in L1 subject education is particularly lacking in the current EMI literature and this is one area this study invests in.

3. Exploration of explicit instruction on language in EMI classes is also lacking in the existing EMI literature. This is another area of classroom interaction that is focused on in this study.

4. EMI teachers' and students' beliefs about effective teaching of the subject matter are rarely explored, although they bear direct influence on pedagogical practices. This study consults the abundant literature in L1 science education, where teacher beliefs about science teaching are widely explored, and applies the expertise to EMI contexts.

   Similarly, EMI teachers' and students' beliefs about effective language teaching in EMI classes, which is another pedagogical concern in EMI classes, are also under researched. This study adopts the frameworks in SLA, e.g., Interaction Hypothesis (Long, 1996) and teacher language awareness (TLA) (Andrews, 2007), to understand this issue.

5. The attention to students in this study marks another area of contribution, while teachers are often the key focus in the research on classroom interaction and beliefs. The quantity

and types of student questions in EMI classes, which is under explored in the exiting literature, is examined in this study. Students' own beliefs about science and language teaching, including EMI teachers' identity and TLA, are also explored. Understanding students' beliefs also allows comparison with their teachers' beliefs.

6. The exploration of teacher beliefs and student beliefs can provide data triangulation to help understand the classroom interaction in the EMI science classes in foreign high school programs in China, which is often missing in classroom interaction research.

Informed by the literature discussed in this chapter, the following research questions are proposed:

1. What are the features of the classroom interaction in EMI science classes between foreign monolingual science teachers and Chinese students in foreign high school programs in China?

2. What are foreign monolingual science teachers' professional background and their beliefs about teaching science to Chinese students through English only, particularly about the role of interaction?

3. What are Chinese students' beliefs about learning science through English only, particularly about the role of interaction, in EMI science classes taught by monolingual teachers?

Chapter 3 Methodology

This chapter presents the research methodology this study employed. First, an overview of the research design is provided in Section 3.1. Then, Section 3.2 describes the target populations and the samples of this study, followed by Section 3.3 about the pilot study. Section 3.4 details the development of the data collection instruments and processes. Sections 3.5, 3.6, 3.7 respectively explain the data analysis procedures for classroom observation data, questionnaire data and interview data. The final section, Section 3.8, considers the ethical issues.

3.1 Research design

This study is exploratory by nature to understand the classroom interaction and teachers' and students' beliefs in the newly emerging foreign high school programs in China. The core of this research is the exploration of the classroom interaction between monolingual science teachers and Chinese students through naturalistic observation, where inferences were made regarding the opportunities there were for learning science and English. The teachers' and students' beliefs, explored through questionnaires and interviews, provided information as to what they perceived was effective teaching of science and English in EMI science classes. The beliefs held by the teachers and students and the discrepancies between the two provided possible explanations of the classroom interaction behaviour observed. The foreign monolingual teachers' professional background was also enquired about through a questionnaire, which also provided certain insights to understand the classroom interaction behaviour.

The way the research questions relate to each other is visualized below in Figure 1.

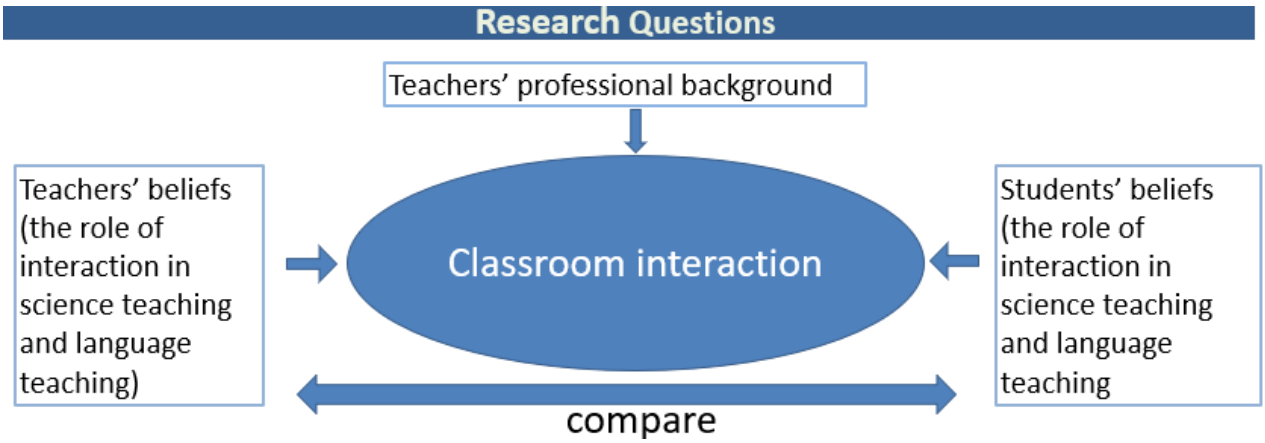


Figure 1 relationship among research questions

3.1.1 The rationale of using a mixed-methods design

A mixed-methods design was adopted in this study, where both qualitative methodology and quantitative methodology were employed in the exploration of classroom interaction and beliefs. Johnson, Onwuegbuzie & Turner (2007) highlighted the key feature of the mixed-methods design as the combination of qualitative and quantitative research approaches in data collection, analysis and interpretation for the purpose of reaching breadth and depth of understanding. It is widely argued that such mixing of methods has the advantage of creating a more complete picture of the research issue through evidence gained from multiple perspectives (Creswell & Plano Clark, 2017; Greene, 2007; Johnson & Onwuegbuzie, 1973). The integration of qualitative and quantitative traditions was considered the most appropriate for this study to obtain a comprehensive and detailed understanding of the classroom interaction behaviour between monolingual EMI science teachers and Chinese students, and their beliefs.

The rationales of mixed-methods research are often discussed with the aim of data triangulation (Creswell & Creswell, 2018; Herrmann, Flick, Garms-homolova, Kuck, & Ro, 2012; Tashakkori & Teddlie, 2003). To achieve data triangulation in a mixed-methods study, the following ways of mixing qualitative and quantitative methodologies are commonly used - 1). the use of quantitative and qualitative data to examine the same issue to enhance the confidence in the findings; 2). the use of quantitative and qualitative data to explore different aspects of the target issue, where data from

different sources provide feedback to each other; 3). the use of quantitative and qualitative data in a sequential manner, where one type of data is used to inform the development of the other type (Greene, Caracelli, & Graham, 1989). The first rationale motivated the use of the mixed-methods design in the investigation of each of the three research questions in this study, i.e., classroom interaction, teacher beliefs, and student beliefs. The second rationale motivated the connections made across the findings of classroom interaction, teacher beliefs, and student beliefs where possible explanations of classroom interaction behaviour were found.

To achieve an accurate understanding of classroom interaction, both quantitative analysis and qualitative analysis of the coded target interaction behaviours were conducted. The quantitative results show the frequency and time duration of the target behaviours whereas the qualitative data illustrates the content and pattern of the quantified behaviours. While the quantitative results mapped out the overall behaviour patterns in a fairly large number of 30 lessons, the qualitative analysis helped to understand the process of how the quantified behaviour took place and thus understand more accurately what was really happening in the classrooms. The details of the data analysis methods are given in Section 3.5 later. To understand comprehensively teacher beliefs and student beliefs, similarly, quantitative data and qualitative data were used to complement each other. Questionnaires were used to obtain mostly quantitative data and interviews were used to elicit in-depth qualitative data, where the quantitative results were validated, explained or questioned. This enabled enhanced confidence in the findings about teacher and student beliefs. The details of the use of questionnaires and interviews are given in Sections 3.4.2 and 3.4.3 later, and the data analysis methods for them are in Sections 3.6 and 3.7.

At the stage of interpreting the findings, results about teacher beliefs, student beliefs, and classroom interaction were compared and connected. Teacher and student beliefs and the discrepancies between the two provided insights to understand the classroom interaction behaviour observed. The data on these three issues provided feedback to each other and allowed a deeper understanding of the teaching and learning in the EMI science classes with monolingual teachers in the target school programs. This rationale of a mixed-method design is mostly demonstrated in Chapter 7 Discussion and Conclusion.

3.1.2 An overview of the data collection and analysis methods

Table 1 below demonstrates the corresponding research instruments for each research question, as well as the data collected and methods of data analysis as an overview of this chapter.

Research questions	Research instruments	Data collected	Methods of data analysis
1. What are the features of the classroom interaction in EMI science classes between foreign monolingual science teachers and Chinese students in foreign high school programs in China?	video recorded classroom observations	30 lessons by 15 teachers	Qualitative and quantitative analysis of the observed lessons to characterize the teacher-whole class interaction
2. What are foreign monolingual science teachers' professional background and their beliefs about teaching science to Chinese students through English only, particularly about the role of interaction?	teacher background questionnaire teacher beliefs questionnaire a pre-lesson interview with teachers before each lesson observations a post-lesson interview with teachers after each lesson observations a general interview with teachers on beliefs	15 teacher background questionnaires 15 teacher beliefs questionnaires 30 pre-lesson teacher interviews 30 post-lesson teacher interviews 15 general teacher interviews	Qualitative and quantitative of the questionnaire data (e.g., descriptive statistics) Qualitative analysis of the teacher interviews (e.g., identifying main themes)
3.What are Chinese student beliefs about learning science through English only, particularly about the role of interaction, in EMI science classes taught by monolingual teachers?	student beliefs questionnaire a post-lesson interview with students after each lesson observations	331 student beliefs questionnaire 30 post-lesson student interviews	Qualitative and quantitative analysis of student beliefs questionnaires (e.g., descriptive statistics) Qualitative analysis of students' post-lesson

			interviews (e.g., identifying main themes)

Table 1 an overview of the data collection and analysis methods

3.1.3 Reasons of not using a comparison design

While this study aims at exploring the monolingual EMI teachers' interaction behaviour, a comparison design between monolingual and bilingual EMI teachers may be desirable. However, during school visits it was found difficult to recruit bilingual EMI teachers who were proficient enough in English to ensure the medium of instruction was mostly in English, not Mandarin. The Canadian programs also tended to only have monolingual Canadian science teachers and no bilingual science teachers who can speak both English and Mandarin. Another possible comparison is between monolingual EMI science teachers and monolingual CMI science teachers. Similarly, this design was also difficult to realize because the curricula taught in the foreign high school programs and the Chinese high school programs are different The students' academic background also may not be matching. Thus, this study only explored monolingual EMI teachers' classes.

3.2 Population and sample

This section first presents the target populations of this study and then the samples collected.

3.2.1 The target school population, teacher population and student population

The features of the target populations of this study will be described regarding the target school population, the teachers and the students. The sampling frame and sampling procedure followed will also be detailed.

3.2.1.1 The target school population

The key features of the target school population are discussed in Chapter 1 Introduction and Chapter 2 Literature Review. In summary, the target school population is the high school programs in China where an Anglophone curriculum is taught by a high number of foreign monolingual teachers to a homogenous group of Chinese students through English.

It needs to be noted that most of the foreign high school programs I visited also require students to take courses in the Chinese provincial high school curriculum, which are conducted in Mandarin by Chinese teachers. The purpose is for them to also obtain the Chinese high school diploma while studying in a foreign high school program with a prospect of attending a university overseas. These CMI classes often take place in the later afternoons or evenings after the EMI classes. Based on the conversations with teachers and students during my fieldwork, the focus of their learning was on the foreign curriculum and the Chinese curriculum was only to ensure they could have the Chinese high school diploma. However, this observation raised a concern. If there is the availability of CMI science classes , this may change the way the students interact with their EMI monolingual teachers.

To tackle this problem, in the post-lesson interviews both the teachers and students were asked how the CMI science classes influenced their behaviour in the EMI science classes (see Question 6 in teachers' post-lesson interview in Appendix 3 and Question 6 in students' post-lesson interview in Appendix 5). According to the students' explanations in their interviews, the science content taught in the CMI science classes was less complicated than the content taught in EMI science classes and thus there was usually a lot to learn in the EMI classes. In the Chinese high school education system, the exams for high school diploma are different from the exams for college admission. The latter is considerably more competitive and demanding. Thus, it is understandable that the students considered the subject content taught in the CMI science classes is easier than the EMI science classes. Thus, the EMI classes in this study are still largely an environment where students learn new subject knowledge through English. The specific findings in this aspect are provided in Chapter 5 and Chapter 6.

3.2.1.2 The target teacher population

The target teacher population of this study is the foreign monolingual science teachers in the target school programs who are highly proficient English speakers with no functioning Mandarin to use in their teaching.

3.2.1.3 The target student population

The target student population is local Chinese students who study in the target school programs. They are aged 16-18. Foreign students are not included. The students in the foreign high school programs usually have a clear goal of attending a university overseas and often have an affluent family background. Due to the lack of official documentation of the foreign high school programs in China, it is difficult to describe the target students' academic attainment and English proficiency level. However, based on teachers' description of their students in my fieldwork, there seemed to be a wide range of levels of academic attainment and English proficiency.

3.2.2 The sampling frame and sampling procedure

The sampling frame of this study aimed to ensure a high level of internal and external validity of the samples. 'Internal validity' of the sample refers to the degree the sample allows the research to answer what the research questions ask to be examined (Lewis-Beck et al., 2003; Robson, 2011). To achieve a high level of internal validity of the samples, the following criteria were followed:

a. The school should have at least one foreign high school program, e.g., A-level, Canadian British Columbia program/IB etc.

b. The school must have foreign science teachers who have a high proficiency level of English and cannot use Mandarin in their classes.

c. The science classes need to have at least 10 students. This minimum requirement is informed by my fieldwork where science classes of this size seemed normal in some foreign programs.

d. The students should be all Chinese locals and there should not be foreign students.

External validity concerns how well the findings from the sample represent the situation of the wider population, which essentially is about generalizability, i.e., the degree to which the findings can be applied to the target population (Cohen, Manion, & Morrison, 2007; Robson, 2011). On top of the criteria above, the following principles were also applied in selecting schools to ensure a reasonable level of generalizability of this research.

e. The school sample should include schools from different regions of China and from different sizes of cities. This means that schools in the sample cannot be only from the top big cities.

f. Schools of different levels of academic and English performance should be included. This ensures that the sample does not only represent the situation in high achieving or low achieving school programs.

g. A variety of foreign curricula should be included in the sample, e.g., the Canadian British Columbia program, the British IGCSE, A-level, IB and so on.

h. School programs with different lengths of history (e.g., 10 years of establishment of their IB program) and of different sizes, e.g., the number of students, should be included.

As aspects of this study are exploratory by nature, it was the aim of this study to represent possible variations in the school population. Thus, the principles listed above, e-h, also align with the exploratory nature of this study.

The sampling procedure adopted aimed to fulfil the criteria set out in the sampling frame. Although random sampling is often considered the most effective way to ensure the external validity of the sample with each member in the target population having an equal probability of being sampled (Paltridge & Phakiti, 2015; Robson, 2011), there are several reasons why it was not adopted in this research and convenience sampling was resorted to. First, there was a lack of official documentation about the distribution and background information about the foreign high school programs in China. Thus, there was not a list of schools to randomly choose from. In addition, contacting schools directly proved to be not an effective way of gaining access. Thus, in the end convenience sampling

was used, where schools were recruited through personal contacts. The details of obtaining consent are explained under Section 3.8 Ethics.

Although the lack of official documentation on such programs made it hard to evaluate the extent to which the schools contacted represented the actual variations in the target school population, consistent effort was made within the capacity and resources available to ensure the schools selected demonstrate at least a certain degree of variation as specified in item e, f, g and h of the sampling frame above. The information that was particularly difficult to obtain was the level of the students' academic and English performance. As one school Principal explained, this information could be commercially sensitive. Another reason was that there were no standardized public exams for such programs. However, teachers were asked to comment on the level of students' English and academic performance in the first pre-lesson interview to at least provide certain insights on this issue. Although the teachers' comments were somewhat subjective, this at least provided some evidence.

To follow items a, b, c, and d in the sampling frame, inquiries were made before school visits to ensure the schools meet these requirements. Upon arrival, the teachers' background questionnaire was distributed to the foreign monolingual science teachers who agreed to participate, and their answers were scanned to ensure their level of English and Mandarin fit the criteria of the target teacher population.

3.2.3 Samples

Following the sampling frame and procedure, this section details the samples of schools, teachers, lessons and students of this study.

3.2.3.1 School sample

The fieldwork of this study started late November 2015 and ended late March 2016 with a total duration of approximately four months. During this time period, nine schools from four provinces across China were visited. Table 2 below gives the information about the school sample.

Geographical location of the school		**School**	**Curriculum**	**mode of operation**	**the year the program started**	**program size (approximate no. of students)**
1.Schools involved in all data collection methods: lesson observation, interviews and questionnaires						
Province A	City 1	Sch 1	Canadian British Columbia	located in a public school	2009	180 Ss
	City 2	Sch 2	British IGCSE, AS, A2	located in a public school	2010	72 Ss
		Sch 3	Canadian British Columbia	located in a public school	2011	180 Ss
		Sch 4	Canadian Alberta	located in a public school	2014	60 Ss
	City 3	Sch 5	American AP program	located in a public school	2014	50 Ss
Province B	City 4	Sch 6	IB program	independent private school	2005	180 Ss
Province C	City 5	Sch 7	Canadian British Columbia	located in a public school	2002	300 Ss

			British IGCSE, AS, A2	located in a public school	2012	60 Ss
2. Schools (or certain classes from a school listed above) involved in student questionnaire only.						
Province A	City 6	Sch 8	Canadian British Columbia	located in a public school	2009	50 Ss
Province B	City 4	Sch 6	British IGCSE, AS, A2	independent private school	2005	50 Ss
Province D	City 7	Sch 9	American AP program	independent private school	2011	360 Ss

Table 2 school sample

As Table 2 above shows, a range of geographical locations, curriculum types, school sizes, and length of history is represented in the school sample. All these four provinces are considered relatively economically developed in China, which is also typically where many of the foreign high school programs are located due to the high fees they normally charge. The seven cities in the sample range from medium to large cities also to represent the possible variations of where the target foreign school programs are located.

Six schools and four cities were from Province A, which leads to an unbalanced representation of schools among the four provinces in the sample. However, this was due to the availability of the access I could obtain. Although there was only one school visited in Province C, because of the larger size of School 7, a higher number of teachers and lessons were observed.

3.2.3.2 Teacher sample

Province	School	Curriculum	T	Subject	Gender	Age	Nationality
Province A	Sch 1	Canadian British Columbia	Emma	Chemistry	F	33	Canadian
			Colin	Physics	M	54	Canadian
			Kate	Biology	F	52	Canadian
	Sch 2	British IGCSE, AS, A2	George	Biology	M	29	American
	Sch 3	Canadian British Columbia	Lennon	Physics	M	25	Canadian
			Louis	Chemistry	M	59	Canadian
			Stella	Biology	F	24	Canadian
	Sch 4	Canadian Alberta	Chris	Physics	M	56	Canadian
	Sch 5	American AP program	Nicolas	Biology	M	34	American
Province B	Sch 6	IB program	Edward	Biology	M	36	American
Province C	Sch 7	Canadian British Columbia	Johnson	Physics	M	24	Canadian
			Jenny	Chemistry	F	23	Canadian
			Christina	Biology/Geology	F	31	Canadian
			Hannah	Biology	F	29	Canadian
		British IGCSE, AS, A2	Mat	Biology	M	32	British

Table 3 teacher sample

The teacher sample of this study is the 15 foreign monolingual science teachers who filled in the teachers' background questionnaire, teacher beliefs questionnaire and whose lessons were observed. A preview of the 15 teachers' background is summarized in Table 3 above, based on their answers to the teacher background questionnaire (see Appendix 1). The teachers' names are all pseudo names to protect the teachers' identity. The full background information of these teachers is provided in Chapter 5.

In Section 4 Language background of the teacher background questionnaire, most teachers wrote 'English' as the first language they learnt as a child in Question 1 and all of them wrote 'English' as their most proficient language in Question 2. Although no English proficiency test was conducted in this study to provide hard evidence of the teachers' English level, the fact that all teachers considered English their most proficient language suggests that they are highly proficient in English. This was also confirmed by the lesson observations.

The teachers' answers to Question 3 of Section 4 of the background questionnaire also shows that no teacher had a functioning level of Mandarin, and no teacher was observed to have used any Mandarin in their lessons. Two teachers, Lennon and Jenny, wrote 'Cantonese' as their first language but 'English' as their most proficient language. Although Lennon's and Jenny's first language is Cantonese, there are substantial differences between Cantonese and Mandarin (Williams & Hutton, 2001; Zhang, Li, & Lau, 2005). This also explains the fact that they cannot use Mandarin in their teaching despite knowing Cantonese. All this information ensured that the teachers in the sample are in the target teacher population of this study, i.e., a high level of English proficiency and no ability of using Mandarin in their teaching.

The 15 teachers observed were of a variety of ages and past teaching experiences in their home countries and other non-English speaking countries. This ensures the data of lesson observations and teacher beliefs can to a certain degree reflect the possible variations in the target teacher population to achieve a reasonable level of external validity of the sample. The variation in the teachers' background also resonates with the exploratory nature of this study. The detailed findings of the teachers' professional background are presented in Chapter 5.

3.2.3.3 Lesson sample

Each of the 15 teachers were observed for two consecutive lessons and all together 30 lessons were observed. The information about the lessons is shown in Table 4 below.

Lesson sample									
School	Curriculum	Teacher	Subject	Grade level	No. of lessons observed	total time of observation	class size	Topic	estimated Ss' academic attainment and Eng proficiency
Sch1	Canadian British Columbia	1.Emma	Chemistry	11	2	2 hrs	24	calculations with moles and molar mass	low
		2.Colin	Physics	12	2	2 hrs	15	gravity, electric charge	low
		3.Kate	Biology	10	2	2 hrs	20	different types of Biomes	low
Sch2	British IGCSE, AS, A2	4.George	Biology	10	2	1.5 hrs	11	different types of sugar, the four macromolecules/biomolecules (protein, sugar, nucleic acid, lipids)	medium
Sch 3	Canadian British Columbia	5.Lennon	Physics	11	2	2 hrs	18	electricity circuit, ampere, voltage, resistors.	medium
		6.Louis	Chemistry	11	2	2 hrs	18	acids and bases	medium
		7.Stella	Biology	10	2	2 hrs	25	structures of plants	medium
Sch 4	Canadian Alberta	8.Chris	Physics	10	2	2hrs	31	reflection and refraction, converging and diverging lenses.	medium

Sch 5	American AP program	9.Nicolas	Biology	11	2	1.5 hrs	10	stem cell research ethics	high
Sch 6	IB program	10.Edward	Biology	12	2	1.5 hrs	10	metabolism, genetic diseases, etc.	
Sch 7	Canadian British Columbia	11.Johnson	Physics	11	2	1.5 hrs	26	sound waves	high
		12.Jenny	Chemistry	11	2	1.5 hrs	26	titration	high
		13.Christina	Biology	10	2	1.5 hrs	26	continent drift theory	high
		14.Hannah	Biology	11	2	1.5 hrs	26	seed plans	high
	British IGCSE, AS, A2	15.Mat	Biology	12	2	1.5 hrs	23	DNA profiling, genetic modification	high

Table 4 lesson sample

As can be seen from the Table 4 above, there were a range of topics taught in the 30 lessons. The estimated students' academic attainment level and English proficiency were also diverse. The class size ranged from 10 to 30 students. All these variations represent the possible diversity in the target school population. However, there was a stronger representation of Grade 11 lessons, Biology lessons, and lessons from the Canadian British Columbia curriculum. Again, due to the lack of official data on the distribution of the foreign high school curricula, it was hard to detect if the distribution of curriculum types in the sample reasonably reflects the variation in the target school population in the country. This constitutes one limitation of this study.

Although there are uneven representations, all the lessons observed were taught by monolingual teachers to Chinese students through English only in foreign high school programs in China. These are the unifying characteristics of the lesson sample.

3.2.3.4 Student sample

The student sample includes two groups. The first group includes all the students who both participated in the lesson observations and also filled in the student beliefs questionnaire. The second group of students only filled in the student beliefs questionnaire but did not participate in lesson observations. The second group of students were either from a school where no lesson observation was conducted, i.e., School 8 and School 9 in Table 5 below, or from a school where lesson observations were conducted with some classes, but other classes were willing to fill in the student questionnaire although they were not in the lesson observations, i.e., School 6 below. The students were aged 16-18. Table 5 below provides an overview of these two groups of students.

Group 1: The students in the 15 classes who were in the lesson observations, shown in Table 4 in Section 3.2.3.3.
Total number of students distributed questionnaires to: 309.
Total number of student questionnaires collected: 217

Group 2: The students who were distributed the student beliefs questionnaire to and did not participate in the lesson observations.
Total number of students distributed questionnaires to: 147.
Total number of student questionnaires collected: 114

The information about the student questionnaires from Group 2 is shown below.

location of the school		school	curriculum	number of questionnaires collected back	estimated English proficiency and academic attainment
Province A	City 6	Sch 8	Canadian British Columbia	67	low
Province B	City 4	Sch 6	British IGCSE, AS, A2	5	low
Province D	City 7	Sch 9	American AP program	42	medium

Table 5 student sample

All together 331 student questionnaires were collected back in person by me from 9 schools across China. 217 of these 331 questionnaires came from Group 1. The other 114 came from Group 2. The questionnaires from both groups were used to understand student beliefs, with details given in Chapter 6. Two students were also selected by the teacher for a post-lesson interview after each lesson observation, resulting in 60 students who participated in the students interviews.

The background information section in the student beliefs questionnaire shows that none of the students had previous EMI experience. The majority stated that they did not go to after-school tutorials. A few students mentioned that they went to IELTS, TOEFL, or SAT tutorials to get more focused training on these exams, such as the test-taking skills, for applying for a university overseas. 10 out of the 217 students reported that they went to CMI Maths, Calculus or Science after school tutorials because they felt they understood the content knowledge more clearly through Chinese. However, these are all rare cases and thus considered not posing significant influence on the classroom interaction behaviour with the foreign teachers in the EMI science class.

Regarding the level of academic and English performance of the 15 classes of students who participated in the lesson observation (i.e., Group 1), three classes of students were perceived by their science teachers as at a low level of English proficiency and academic performance, five at medium, and seven at the high level. This shows a slightly heavier representation of a high level of academic attainment and English proficiency. However, the sample of students for questionnaires (i.e., Groups 1 and 2) showed a more even representation with six classes of students being perceived as respectively at a low and medium level each and seven classes at a high performance level.

As explained earlier, the teachers' comments were a subjective measurement. However, as Table 4 in Section 3.2.3.3 shows, the estimation of their students' academic attainment and English proficiency from different teachers at the same school aligned with each other. For example, Teachers 5, 6, 7 at School 3 all commented that their class of students were at a medium level. This alignment of different teachers' comments within one school indicates a certain level of validity in their judgement.

3.3 Pilot study and its implications for the main data collection

A pilot study was undertaken to trial the data collection instruments, familiarize myself with the context of the foreign high school programs in China, and to examine the logistics of this research. It took place between 5 May 2015 and 26 May 2015 in a public high school in East China, where a Canadian British Columbia provincial high school program was hosted. All teachers were Canadian, except one Chinese ESL teacher. The class size was about 15-20 students.

Lesson observations (n=14) were conducted with six lessons observed from one Grade 12 Chemistry teacher, six from one Grade 11 Physics teacher, and two from one Grade 10 Integrated Science teacher. Pre-lesson interviews (n=14) were held with the teachers before each observation and post-lesson interviews (n=14) were conducted after each observation with the teachers. Post-lesson interviews (n=6) were also held with students after six lesson observations. Among them, two were focus groups with four Grade 12 students in each interview, and three were focus groups with three Grade 11 students in each interview. One of the student interviews was an individual interview with one Grade 12 student.

Teachers' background questionnaires (n=3) and beliefs questionnaires (n=3) were collected from the three science teachers. Student beliefs questionnaires (n=30), which were translated into Chinese, were also collected from 15 Grade 12 students and 15 Grade 10 students.

The following is a summary of the key improvements made for the main data collection.

- Because of the minimal student participation observed during the pilot study, new questions were added in the student beliefs questionnaire to explore the reasons. For example, in Section 3, the following question was added – '*2). In science classes, sometimes I know the answers to teacher questions, but I don't answer because I am afraid of speaking in English*' and '*3). In science classes, sometimes I know the answers to teacher questions, but I don't answer because I don't know how to phrase it in English*'. Similarly, under Section 5, the following questions were added – '*2.2). What are the major challenges for you to participate, if there are any?'.*

- Some changes were made to the teacher beliefs questionnaire to emphasize it was the general belief that was enquired about. For example, under Section 1, an extra line of explanation was added in the instruction – '*Based on your **overall beliefs** about how science should be taught **in general**…*'. '*In most situations*' were also added to Question 3 under Section 1 – '*Teacher monologue of explanation **in most situations** is more effective….*'.

- The teacher beliefs questionnaire was shortened by moving some open-ended questions to the general teacher interview, where teachers can provide verbal answers rather than written ones, as at the pilot study the questionnaire took as long as about 45 minutes to complete.

- To make sure there was enough time for pre-lesson interviews before each lesson, in the main data collection teachers needed to be informed and asked to pick a suitable time in advance.

- To keep teachers' memories fresh of their teaching in the lessons observed, it was important to have the post-lesson interviews as soon as possible after the observations.

- Focus groups were found not an effective way of eliciting rich views from students, where they are expected comment on and respond to each other's opinions (Krueger, 1994). The students often tended to agree with each other and were found not comfortable with sharing much of their own experience or opinion, which defeats the purpose of focus groups (Krueger, 1994). However, in the individual interview, more elaborations and detailed description of opinions were able to be elicited. In addition, focus groups with four or three students were also found to take a lot of time which could get in the way with the tight timetable schools have. Thus, it was decided that in the main data collection post-lesson interviews with two or three individual students independently would be conducted instead.

- It was observed that having the interviews in the teachers' office might have discouraged teachers or students from freely expressing their views. In the main data collection effort was needed to arrange a quiet and more private place to have the interviews, such as an empty office.

- It was noticed in the students' questionnaires that some students left some questions unanswered. Thus, a line of explanation, '*please make sure you answer all questions'*, was added in the introduction to highlight the importance of answering all questions.

3.4 Instrumentation and procedures

This section first details the development of the research instruments used in this study, with Section 3.4.1 focusing on questionnaires, Section 3.4.2 on classroom observation and Section 3.4.3 on interviews. The data collection procedure of employing all these instruments is described in Section 3.4.4.

3.4.1 Research Question 1 - classroom observations

Naturalistic non-participatory classroom observations were conducted to observe the classroom interaction behaviour in the 30 lessons, addressing Research Question 1. Naturalistic non-participatory observation (Markee, 2007; Stodolsky, 1990) was adopted because the purpose of this research is to explore how monolingual science teachers and Chinese students interact in their everyday EMI lessons. It was important to make sure my presence did not intervene or change how the lessons were normally conducted.

Each teacher was observed for two consecutive lessons so that it was more likely to capture the teachers' ordinary teaching behaviour. This was because observing one lesson may run the risk of encountering a lesson with a special design, which may result in interactional behaviour that was less representative. Observing more than two lessons was very difficult due to teachers' busy schedule. In addition, the pilot study also shows that the classroom interaction pattern in the six lessons observed for the two teachers did not change significantly over the course of these lessons.

3.4.2 Research Question 2 - teacher background questionnaire, teacher beliefs questionnaire and interviews

3.4.2.1 Teacher background - teacher background questionnaire

Questionnaires were used to collect teachers' background information to answer part of Research Question 2. As Dornyer & Taguchi (2010) explained, questionnaires are an efficient and convenient way to collect a large amount of information. In the teacher background questionnaire (see Appendix 1), Section 1 captures the teachers' basic demographic information, including gender, age, and nationality. Section 2 concerns the teachers' past teaching experience in L1 and L2 contexts and Section 3 enquires about teachers' academic qualifications and training

experience. Section 4 investigates the teachers' language background to ensure the teachers are in the target teacher population.

In Section 4, Questions 1 and 2 were aimed to confirm if the teachers are highly proficient in English. The term 'native language' was not used because of the challenges of defining a native language (Llurda, 2005; Moussu & Llurda, 2008). However, if the teacher writes English as his/her most proficient language, he/she is probably highly proficient in it. Proficiency in Mandarin was also specifically asked about in Question 3 to check if the teachers are indeed monolingual teachers who are not able to use students' L1 in their teaching. Question 3 in Section 4 was informed by the literature reviewed in Section 2.5.1 in Chapter 2, where it was discussed that a teacher's own language learning experience could influence how they teach languages (Ellis, 2006; Woods, 1996).

3.4.2.2 Teacher beliefs - teacher beliefs questionnaire and teacher interviews

To answer Research Question 2 on teacher beliefs about teaching science and English in EMI science classes, both questionnaires and interviews were employed. The teacher beliefs questionnaire elicited mostly quantitative data through multiple-choice questions. The interviews, which were semi-structured and included a pre- and a post-lesson interviews for each lesson observation and a general interview with each teacher, elicited substantial explanations from the teachers to complement the questionnaire data. As Borg (2006) argues, teacher beliefs are often highly individualized. Thus, the open-ended nature of interviews can provide the space for the teachers to freely explain their individualized views which may not be covered by the teacher beliefs questionnaire. Flick (2018) also argued that the rich and in-depth data of interviews are valuable in understanding complex constructs, such as beliefs, where questionnaire data can often only provide a rather surface level of assessment. Thus, the combination of the use of questionnaire and interview was considered the most appropriate to gain a comprehensive understanding of teachers' beliefs.

In the literature of exploring teacher beliefs, video stimulated recall is frequently used to elicit teachers' detailed recount of the thought processes at a certain moment of a lesson, through which beliefs can be reflected (Calderhead, 1981; Stough, 2001). Stimulated recalls often start with the replay of certain episodes of a lesson and the teachers are asked to verbalize their decision-making processes (Borg, 2006). It is also often regarded as an effective tool for teacher training (Meade & McMeniman, 1992; Tripp, 2010). Although stimulated recall is a well-recognized method to explore teacher beliefs, however, they were not used in this research because of most teachers' lack of time to commit to the procedure. Nevertheless, effort was made in the post-lesson interviews to elicit teachers' reflection of their specific acts in the lesson just observed.

3.4.2.2.1 Teacher beliefs questionnaire

The teacher beliefs questionnaire (see Appendix 2) consists of two sections – Section 1 on teaching science and Section 2 on teaching English in EMI science classes. This questionnaire is largely formed by multiple-choice question items, thus providing mostly quantitative data. Both sections consist of items borrowed from existing questionnaires and new items developed to better tackle the issues focused on in this current study.

a.Section 1 of the teacher beliefs questionnaire

Section 1 measures the construct of 'teachers' beliefs about teaching science, with a focus on interaction'. It evaluates the degree to which the teachers' beliefs align with the constructivist view of teaching science, particularly regarding the role of interaction. As DeVellis (2016) explained, theory and literature can be an aid to provide clarify in developing scales. Based on the discussion in Sections 2.3.2 on constructivism and 2.3.4 on the past EMI/CLIL literature on classroom interaction, six subscales were identified as important to include:1). the role of previous knowledge, 2). the role of practical activities, 3). the role of students' substantial output, 4). teacher-student interaction vs. teacher monologues, 5). interaction among students themselves, 6). types of teacher questions.

As explained in Section 2.3.2 in Chapter 2, the constructivist view of teaching sees interaction between teachers and students and among students themselves as central to learning, where students confront their misconceptions and reconstruct their knowledge through social interaction. The Dialogic Approach (Alexander, 2000; 2004) also particularly highlighted the importance of students' substantial explanations of their ideas. Thus, Subscales 1), 3), 4), and 5) were formed. Additionally, what also motivated the formation of Subscales 3) and 4) was the strong teacher dominance and a general lack of student output frequently observed in previous EMI/CLIL literature (e.g., Dalton-Puffer, 2007; Lo & Macaro, 2012; Yip et al., 2007), explained in Section 2.3.4.1 in Chapter 2. The formation of Subscale 6) was motivated by the significance of teacher questions in classroom interaction (Erdogan & Campbell, 2008; Long & Sato, 1983; Mehan, 1979) and the heavy use of recall questions and limited use of higher-order thinking questions frequently reported in previous EMI/CLIL literature (e.g., Menegale, 2011; Schuitemaker-King, 2012; Sopia et al., 2010), as explained in Section 2.3.4.2 in Chapter 2. Subscale 2), despite not directly related to classroom interaction, was also considered an important aspect to include as the use of practical activities is a crucial issue for science education (Jenkins, 2000; Marshall, 1992), discussed in Section 2.3.2.

Table 6 below lists the items in each subscale of Section 1, the corresponding sections in Chapter 2 where the significance of the six subscales were discussed, and the sources of the items, which will be explained below.

Section 1 Science teaching in general			
Item	Sub-scales	The corresponding sections in Chapter 2 Literature Review	The source of the items
2,5,6,11,15	1.The role of previous knowledge (i.e. whether teachers should start from knowing students' existing understanding when introducing new knowledge);	Section 2.3.2	2, 6, 15 newly developed; 5 and 11 adapted from Sampson et

			al.'s (2013) questionnaire
7,9	2.The role of practical activities (i.e. whether students should do experiments before learning new knowledge as a way to explore the new concept)	Section 2.3.2	7 and 9 adapted from Sampson et al.'s (2013) questionnaire
8, 10, 13	3.The role of students' substantial output (i.e. whether students' detailed explanations of their own thoughts/views help students learn science)	Section 2.3.2; Section 2.3.4.1	8 and 13 newly developed 10 adapted from Sampson et al.'s (2013) questionnaire
1,3	4.Teacher-student interaction vs. teachers' monologue		1 and 3 newly developed
4, 12	5.Interaction among students themselves		4 and 12 adapted from Sampson et al.'s (2013) questionnaire
14, 16	6.Types of teacher questions	Section 2.3.2; Section 2.3.4.2	14 and 16 newly developed

Table 6 the theoretical basis of the subscales of Section 1 of teacher beliefs questionnaire

After identifying the subscales to include in Section 1 of the questionnaire, reference was made during the generation of items to an existing validated teacher beliefs questionnaire - BARSTL (Beliefs About Reformed Science Teaching and Learning), developed by Sampson et al. (2013). BARSTL was developed to assess the alignment of US school science teachers' beliefs about teaching science with the recent science education reform, which promoted a constructivist view of teaching (NRC, 1996). BARSTL follows the same theoretical framework as this study and has a high standard of content and construct validity and reliability (i.e., Cronbach alpha being 0.77) through vigorous trialling, as explained in Sampson et al. (2013). This made it an appropriate reference for this study.

BARSTL consists of four subscales with a total of 32 items, measuring a).how people learn about science, b). lesson design and implementation, c).characteristics of teachers and the learning environment, and d). the nature of the science curriculum. As BARSTL is an elaborate questionnaire exploring teachers' beliefs about science education in a comprehensive manner,

only the items that were closely relevant to the subscales identified above were adapted in this study. These items include Items 4 and Items 5 from Subscale a) in BARSTL, Item 5 from Subscale b), and Items 10, 11 and 12 from Subscale c), as also shown in Table 6 above. A detailed explanation of the source of the items, including the original items in Sampson et al.'s (2013) questionnaire and the adaptations made, is in Appendix 7.

In the adaptation of these items, certain items were paraphrased to be more accessible and concise (De Vaus, 2008) to reduce the time needed for the teachers in this study to complete the questionnaire. For example, Items 4 and 12 in Subscale 5 of this questionnaire were shortened versions of Items 8 and 18 in BARSTL, with details given in Appendix 7. In addition, some items were paraphrased to negate the constructivist view as it has been found that participants tend to agree with the question items given and researchers are advised to include statements showing preferences to different viewpoints (Borg, 2006; Munn & Drever, 1999). For example, Item 4 was paraphrased to express a transmissionary view, negating the constructivist view in Item 8 in BARSTL. The distribution of the viewpoints of items is given in Table 7 below.

Since BARSTL is not designed to specifically focus on interaction, new items were also developed. These new items include Items 1, 2, 3, 6, 8, 13, 14, 15 and 16. As shown in Table 6 above, Items 1 and 3 made up Subscale 4 and Items 14 and 16 made up Subscale 6. The other subscales already consist of items borrowed from BARSTL but are further substantiated by the new items developed. In the generation of these new items, effort was also made to ensure the items were clear, concise, and brief, which are important for questionnaire construction (De Vaus, 2008). For example, Item 1 - '*Interaction between teacher and students is important for learning science*', is an example of how it was tried to make the wording more succinct.

The item allocation of the views is shown in Table 7 below.

Section 1 beliefs about teaching science	Item allocation
Constructivist view	1, 5, 7
Transmissionary view	2, 3, 4, 6, 8, 9,10,11,12,13,14,15,16

Table 7 item allocation for Section 1 of teacher beliefs questionnaire

It is noted in the literature that the more items there are to measure a dimension of a construct, the more reliable and accurate the scale is (Paltridge & Phakiti, 2015). However, the number of items in each of the six subscales of Section 1 was deliberately kept low. This was because the core of this study lies in the exploration classroom interaction. In addition, the teachers' commitment to lesson observations and interviews already took substantial time away from their schedule. However, the content validity of Section 1 of this questionnaire (Gall, Borg, & Gall, 1996)., i.e., whether the items do evaluate the alignment of the teachers' beliefs about teaching science to the constructivist view of teaching science, with a focus on interaction, was ensured by two science experts, with the validation that was already shown in Sampson et al.'s (2013) questionnaire.

Regarding the assessment of the reliability this section, the teacher sample of 15 is too small to calculate Cronbach's alpha to evaluate the internal consistency. Internal consistency refers to the extent to which the items that make up a scale measure the same underlying construct (DeVellis, 2016). It is a key indicator of the reliability of a scale, i.e., how consistently the questionnaire reflects the construct that is measuring. However, Cronbach's alpha was calculated for the equivalent section in the student beliefs questionnaire, Section 4, which will be explained in Section 3.4.3.1 of this chapter later.

Although the value of a mixture of closed and open questions is believed to have the potential of providing rich explanations (Nunan, 1992), open-ended questions were not included in this section because the teachers were also invited to a general interview to elaborate in depth on their beliefs, as explained in Section 3.4.2.2.2 below.

b.Section 2 of the teacher beliefs questionnaire

Section 2 of the questionnaire measures the construct of 'teachers' beliefs about teaching English in EMI science classes, with a focus on interaction'. As already explained in Section 2.5.4 in

Chapter 2, this construct consists of EMI teachers' language awareness (TLA), EMI teachers' identity as language teachers, and EMI teachers' beliefs about the role of interaction for language development. TLA also consists of three components, as explained in Section 2.5.4.1. The item allocation of the subscales is shown in Table 8 below. As one of the key characteristics of this study is the monolingual teacher population, Question 21 was added to investigate teachers' views of monolingual teachers vs. bilingual teachers. This was also motivated by the number of possible differences monolingual teachers may bring to teaching and learning in EMI classes, explained in Section 2.4 in Chapter 2.

Similar to Section 1, this section is also made up by items borrowed from existing questionnaires and items that are newly developed. Again, the source of each item and the adaptations made are given in Appendix 7.

Section 2 English language teaching in EMI science classes				
Item	Sub-scales		The corresponding sections in Chapter 2 Literature Review	Source of items
19	Teacher language awareness (Andrews, 2007)	1).Teacher's own proficiency of the language of science	Section 2.5.4.1; Section 2.5.4.2	19 newly developed
14, 16, 18		2).Teacher's own knowledge about the English language	Section 2.5.4.1; Section 2.5.4.2	18 newly developed 14 and 16 adapted from Hoare's (2003) questionnaire
3, 4, 8, 9, 10, 15, 17, 20		3).Teacher's understanding of Chinese students' difficulties in the language of science and general English	Section 2.3.4.4.2.2; Section 2.5.4.1	

		3.1).Teacher's understanding of EMI students' language difficulties in the language of science and general English – Items 3, 4, 8, 9, 10		3, 4, 10 newly developed 8 and 9 adapted from Lo's (2014) questionnaire
		3.2).Teacher's attitude of the need to know about Chinese students' language difficulties in the language of science and general English – Items 15, 17, 20		15, 17, 20 newly developed
1,2, 5	4).Teachers' perceptions of their role as a language teacher		Section 2.5.4.2	1, 2, 5 adapted from Lo's (2014) questionnaire
6, 7 11 (1,2), 12, 13 (1,2)	5).Teachers' understanding of how interaction promotes L2 learning		Section 2.3.3; Section 2.5.4.3	11 (1, 2) newly developed 6 and 7 adapted from Lo's (2014) questionnaire 12, 13 (1, 2) adapted from Hoare's (2003) questionnaire

Table 8 the theoretical bases of items in Section 2 of teacher beliefs questionnaire

As can be seen in Table 8 above, references were made with Lo's (2014) questionnaire and Hoare's (2003) questionnaire. Lo's questionnaire was designed to examine English language teachers' and EMI content teachers' perceptions of their roles, and Hoare's (2003) questionnaire was developed in a doctorate thesis to evaluate EMI science teachers' language awareness. Both questionnaires were set in the context of EMI secondary schools in Hong Kong. The decision of referring to these two questionnaires was based on their relevance to the components of the construct investigated in this questionnaire, particularly teacher language awareness and EMI teachers' role as language teachers. Hoare's questionnaire was also particularly relevant as it was designed for EMI science teachers. The Cronbach alpha of Lo's (2014) questionnaire for EMI

content teachers is 0.86, thus demonstrating a high level of reliability (DeVellis, 2016). The reliability of Hoare's (2003) questionnaire was not assessed statistically as the number of teachers, six, was too low, but the questionnaire was trailed in a pilot study.

Lo's questionnaire, as reported in the study in 2014, includes five sections - 1). content subject teachers' beliefs about their and English teachers' roles in English medium education; 2) English teachers' beliefs about their roles in English medium education; 3). teachers' language teaching awareness or practices in lessons; 4). teachers' beliefs about the effectiveness of cross-curricular collaboration; 5).teachers' attitudes towards cross-curricular collaboration. Only Sections 1 and 3 in Lo's questionnaire are directly related to the components of the construct in this questionnaire, and items from these two sections helped to form Subscales 3.1), 4) and 5) in the student beliefs questionnaire in this study.

Items 2 and 3 under Section 3 *Teachers' language teaching awareness or practices in lessons* in Lo's questionnaire were adapted to make Items 8 and 9 in Subscale 3.1). The original items in Lo's questionnaire describe what teachers would do regarding teaching vocabulary and grammar in their lessons. Adaptations were for the purpose of making the items sound more in line with descriptions of beliefs rather than practice.

Items 1, 2 and 5 in Subscale 4) of this questionnaire were adapted from Items 1 and 2 in Section 1 *Content subject teachers' beliefs about their and English teachers' roles in English medium education* and Item 1 of Section 3 in Lo's questionnaire. Item 1 in this questionnaire describes a general attitude of focusing on English in EMI science classes. Item 2 specifically asks about the role of academic English that is commonly required for learning science in English. Modifications were made to gear Item 2 more towards the context of EMI science lessons rather than EMI classes in general.

Items 6 and 7 in Subscale 5) were adapted from Item 2 of Section 1 in Lo's questionnaire. Items 2 concerns the role of corrective feedback, which is an important mechanism of how interaction promotes L2 development (Long, 1996), as explained in Section 2.3.3 of this thesis. Thus, it was

considered highly relevant to the purpose of this study. Adaptions were made to separately ask about the role of corrective feedback to students' oral output and written output.

Hoare's (2003) questionnaire also provided the basis of some items in this questionnaire. The concept of language awareness in Hoare's (2003) study was defined as teachers' recognition of the important role of English in teaching and learning of science in EMI schools and their readiness to accept this role of language. Although the concept in Hoare's study does not exactly align with the concept of teacher language awareness (TLA) used in this study, it is relevant to some subscales. Hoare's (2003) questionnaire explores both teacher beliefs and practice, and thus only Part 3 about teacher beliefs was referred to. This part consists of several sections – 1). vocabulary; 2). resources; 3). role of science teacher in language development; 4). language-related attributes of a science teacher (subcategories: skills, language knowledge, knowledge about second language learning); and 5). opportunities for students to use language purposefully. Among the five sections, Items in Sections 4 and 5 were directly relevant to the construct of interest of this section of the student beliefs questionnaire and borrowed to help form Subscales 2) and 5).

Items 14 and 16 in Subscale 2) of Section 2 of this questionnaire were adapted from Item 20 in Section 4 (Subcategory 2: language knowledge) of Hoare's questionnaire. Items 14 and 16 separately ask about teachers' knowledge about grammar and pronunciation whereas the original item in Hoare's questionnaire asks about them together.

Items 12, 13 (1) and Item 13 (2) in Subscale 5 were adapted from Items 22 and 6 in Section 5 of Hoare's questionnaire. Items 22 and 6 specifically ask about the role of students' regular and lengthy output, an important issue highlighted in Sections 2.3.3 (e.g., Swain, 1995), and 2.3.4.1 (e.g., Macaro, Graham and Woore., 2016), thus they were considered highly relevant to this study. Item 6 in Hoare's questionnaire asks about spoken and written output in one item and Items 13 (1) and 13 (2) in this study separated them. In addition, Items 13 (1) and 13 (2) were also paraphrased to specially highlight the purpose of students' lengthy answers to improve their English. For example, Item 13 (1) is phrased as – '*Having students do work in science that requires them to give long spoken answers in English is helpful for them to improve their English*.'

This is to differentiate this section, which is about teachers' beliefs about teaching English in EMI science classes, from Section 1 on beliefs about teaching science. Item 12 in Subscale was slightly adapted from Item 22 in Section 5 of Hoare's questionnaire and it asks about regular opportunities of output.

New items were also developed, including Item 19 in Subscale 1, Item 18 in Subscale 2, Items 3, 4 and 10 in Subscale 3.1, Items 15, 17 and 20 in Subscale 3.2, and 11(1,2) in Section 5. The purpose mainly lies in addressing the issue of the language of science and general English, and emphasizing the role of interaction for L2 development, as classroom interaction is the focus of this study.

Item 19 in Subscale 1 was developed to address the issue of the language of science in particular. The teachers' own proficiency of general English was not included in Subscale 1 as one of the key features of the monolingual teacher population in this study is high English proficiency, as explained in Section 2.5.4.1 in Chapter 2.

In Subscale 2, to complement Items 14 and 16 borrowed from Hoare's questionnaire on grammar and pronunciation, Item 18 was added to ask in general the teachers' views of their explicit knowledge about the English language.

In Subscale 3.1, Items 3 and 4 and 10 were created to complement Items 8 and 9 borrowed from Lo's questionnaire on vocabulary and grammar. Item 3 was about the language of science and Item 4 was developed to ask if general English is a problem for EMI science students. This was guided by the literature (Clark, 1997; Probyn, 2006; Prophet & Towse, 1999) and reasoning provided in Section 2.3.4.4.2.2 in Chapter 2. Item 10 was developed based on a principle of the Dialogic Teaching approach (Alexander, 2004), explained in Section 2.3.2 in Chapter 2, where science teachers are advised to model how to use English to develop and elaborate ideas about science. This item was considered helpful to reflect teachers' understanding of their EMI science students' language needs particularly in elaboration of their science ideas.

In Subscale 3.2, all three items, 15, 17, 20, were developed by me to respectively explore teachers' attitudes towards whether they should know about their students' language difficulties in the areas of grammar, pronunciation, and the language of science. Items 15 and 17 echo with Items 14 and 16 in Subscale 2, borrowed from Hoare's questionnaire. The issue of the language of science was particularly addressed in Item 20. Subscale 3.2 was considered helpful to be added under the third component of TLA, i.e., teachers' understandings of their students' language needs. This was because EMI students' difficulties with English have been argued as a key issue in the past EMI/CLIL literature (Belhiah et al., 2013; Joe & Lee, 2013; Wu, 2006; Yip et al., 2003), discussed in Section 2.3.4.4 of Chapter 2. Teachers' attitudes revealed in Subscale 3.2 can demonstrate which area of language they believe is important to provide help with.

Items 11 (1,2) in Subscale 5 were developed to particularly address the important role of output in L2 learning, inspired by the findings in previous EMI/CLIL studies showing a general lack of students' output (e.g., Dalton-Puffer, 2007; Lo & Macaro, 2012; Yip et al., 2007), discussed in Section 2.3.4.1 in Chapter 2 Literature Review, as well as the lesson observations during the pilot study of this project.

The same concern was also kept in the generation of the items of this section to make sure the items were concise and clear (De Vaus, 2008). A fair number of items were also phrased to be unfavourable for facilitating language development in EMI science classes to avoid the tendency of agreeing with what is given (Munn & Drever, 1999).

The item allocation of the different standpoints is shown in Table 7 below.

Section 2 beliefs about teaching English in EMI science classes	Item allocation
Favourable view of language teaching	4, 6(1), 7 (1), 8, 10, 13 (1), 13 (3), 15, 17, 18
Unfavourable view of language teaching	1, 2, 3, 4, 8, 11, 12, 14, 16, 19, 20

Table 9 item allocation of Sections 1&2 of teacher beliefs questionnaire

To ensure content validity of this section, an expert in Applied Linguistics checked the items and deemed it having a high level of content validity. Regarding the reliability of this section, again, the teacher sample of 15 is too small to calculate Cronbach's alpha to evaluate the internal consistency. However, Cronbach' alpha was calculated for the equivalent section in the student beliefs questionnaire, i.e., Section 5, which will be explained in Section 3.4.3.1 later.

3.4.2.2.2 Teacher interviews – pre- and post-lesson interviews, general interviews

Semi-structured interviews were conducted with the teachers, including a pre-lesson interview and a post-lesson interview for each lesson observation, and a general interview with each teacher to understand comprehensively their personalized beliefs. Semi-structured interviews were considered the most appropriate for the purpose of this study among the various types of interviews (e.g., structured, unstructured) (Plonsky & Gurzynski-weiss, 2014). This was because, to complement the mostly quantitative data from the teacher beliefs questionnaire, an open space was needed for the teachers to provide their own explanations of the aspects that they thought were important in their beliefs about science and language teaching in EMI science classes. However, to ensure all participants comment on the same set of issues, e.g., the role of interaction, the role of teacher questions, certain structure was also considered necessary. Semi-structured interviews could provide both the open-ended nature and ensure the inclusion of the important themes (Dörnyei, 2007). The purpose and design of each interview are given below.

a. Pre-lesson interviews

As Borg (2006) argued, how teachers plan their lessons to achieve their teaching goals could reveal their teaching beliefs. A brief pre-lesson interview was conducted before each of the 30 lesson observations to understand the teaching objectives and the teachers' teaching plan. The interview protocol is in Appendix 3. A guiding question was pre-prepared - *'What do you plan to do in this lesson and why?'*, which was aimed to open-up the conversation and allow the teachers to elaborate on any issues that they thought were important. In addition, two probing questions were also prepared to ensure teachers' plans to use classroom interaction and talk in

particular were elicited - '*How are you going to make students understand?*' and '*How will you use classroom talk to achieve your teaching purposes?*'.

In the first pre-lesson interview, the teachers were also asked to comment on the general academic attainment and English proficiency of the class of students. This was to understand the background of the students whom the teaching was catering for.

b. Post-lesson interviews

After each lesson observation, a post lesson interview was also held with the teacher. The protocol is in Appendix 3. The aim of this interview was to ask teachers to explain and reflect on their practice in that lesson, including their use of teacher-student interaction, questions and attention to the English language, which could reflect their beliefs about teaching science and English in EMI science classes.

Question 1 was designed to explore if the lesson observed could reasonably represent the teacher's ordinary teaching behaviour. The teacher's answers to this question could provide evidence on how well the observation of the two lessons captured the typical teaching in this teacher's lessons. Question 2 was designed to open up the space for the teacher to provide his/her own comments on how the lesson went and a general description of their experience of teaching the lesson. Question 3 aimed to elicit specific explanations of how they perceived their teaching supported achieving the goals of the lesson. While a guiding question was prepared, probing questions were also in place, in case needed, to ensure the topic of classroom interaction was commented on, thus providing sufficient answers for Research Question 2. Question 4 focused on the challenges of teaching science in English, and teachers' answers of how they tackled the language challenges could reflect their beliefs about English teaching in EMI science classes.

Question 5 was designed in response to the pre-lesson interviews. The teachers' comments on the possible obstacles of implementing their lesson plans could provide insights to interpret the

classroom interaction behaviour. Question 6 explored the possible influence of the parallel CMI science classes on the classroom interaction in the EMI science class observed.

The lesson observation notes were also referred to during the interviews. For example, if the behaviour noted down was about language challenges, this would be asked about under *prob question b. What were the challenges of teaching this topic in English? How did you tackle them* under Question 2.

c. General interview with teachers

An in-depth interview was held with each teacher after the two lesson observations were completed. The interview protocol can be found in Appendix 3. This interview was not specifically attached to any lesson observed but served as a separate interview to elicit teacher beliefs in a comprehensive manner, possibly providing insights on their answers in the teacher beliefs questionnaire, and also bring up issues that are not covered in the teacher beliefs questionnaire.

The leading questions in this general interview covered similar topics as in the teacher beliefs questionnaire. The matching of the questions ensures that the findings from the general interview and the teacher beliefs questionnaire can be compared and complement each other on the same topics. For example, Part B of this general interview corresponds with Section 1 of the teacher beliefs questionnaire. Both aimed to elicit teachers' beliefs on how science should be taught. The key issues in Section 1 of the questionnaire were also covered in the probing questions under Part B of the general interview, e.g., the role of teacher-student interaction, the role of student-student interaction, use of questions and practical activities.

3.4.3 Research Question 3 - student beliefs questionnaire and interviews

Student beliefs about science learning and English learning in EMI science classes were also explored through questionnaires and interviews.

3.4.3.1 Student beliefs questionnaire

The first section of the student beliefs questionnaire (see Appendix 4), 'Background information', enquires about the students' background information, including whether the students had attended EMI programs before and whether they were attending after school tutorials conducted in Mandarin. Section 2 explores the students' motivations for attending the foreign high school program. The information gathered in Section 1 and Section 2 can provide the context of the data of classroom interaction behaviour.

Section 3 'Experience with the foreign science teachers and learning science through English' was designed with reference to Hunt's (2011), Pladevall-Ballester's (2014), and Lo and Macaro's (2012) studies. Here the students were asked about their general experience in the EMI science classes, such as whether they understood the classes. Items about the reasons for not participating in classroom interaction, i.e., Items 2 and 3, were also added. This was motivated by the observation made during the pilot study, as mentioned in Section 3.3 earlier, and the lack of student participation that is often described in the past EMI CLIL literature (e.g., Dalton-Puffer, 2007; Lo & Macaro, 2012; Yip et al., 2007), explained in Section 2.3.4.1. The students were also asked about their preference for a monolingual EMI science teacher or a bilingual teacher. The answers of this question can show the students' attitudes towards the monolingual teachers and their view on L1 use in EMI science classes. This question also matches with Question 21 in Section 2 of the teacher beliefs questionnaire.

Sections 4 and 5 are essentially the same as Sections 1 and 2 in the teacher beliefs questionnaire, respectively enquiring about students' beliefs about science learning and English learning in EMI science classes. Some items were paraphrased to be oriented to students rather than teachers. The matching of these two sections is to enable comparison between the teachers' answers and the students' answers.

Unlike the interview processes with the teachers, no general interviews were conducted with the students to gain a comprehensive understanding of their personalized beliefs about science and language learning in EMI science classes because it was infeasible to conduct such interview with all students. Only a post-lesson interview with two students was conducted after each lesson observation to mostly reflect on the specific lessons observed. Thus, it was decided that the elicitation of qualitative data from each student on their beliefs was conducted in the student beliefs questionnaire. Thus, several open-ended questions were added in the questionnaire beneath the multiple-choice questions in Sections 3, 4 and 5. This combination of quantitative and qualitative factors in one single data collection method is also an example of intra-method mixing in a mixed-method design (Johnson & Turner, 2003).

In Section 3 on students' experience with EMI, open-ended Question 6 was added to elicit students' explanations of the difficulties, if there were any, caused by learning science through English. Open-ended Questions 7 and 8 ask about students' opinions on monolingual teachers. In Section 4, open-ended Questions 17 and 18 ask students to explain their beliefs about learning science and their views regarding the role of interaction. Similarly, Question 21 in Section 5 asks about students' beliefs about learning English in their science classes. Question 22 was added in Section 5 to particularly elicit students' explanations of the difficulties for participating in teacher-student interaction. Again, this was motivated by as a lack of interaction observed in the pilot study and the general lack of student participation frequently reported in previous EMI and CLIL studies.

The student questionnaire was translated into Chinese. The translation was checked by one highly proficient bilingual in English and Chinese, and back translated into English by another English-Chinese bilingual to check if the back translated English version matched with the original version. This process of back translation was to make sure the meaning in the Chinese version did not deviate from the original meaning in English.

After scoring the students' answers and the reversal, the Cronbach's alpha values for Sections 4 and 5 were calculated. The values are 0.70 and 0.82. This indicates a reasonably high degree of

internal consistency in these two sections (DeVellis, 2016; Pallant, 2016). The Cronbach alpha for the subscales were not calculated because of the low number of question items in each subscale. As Pallant (2016) specified, a smaller number of items often leads to a lower Cronbach value, e.g., a scale of 10 items. All subscales in this questionnaire have fewer than 10 items and thus it is difficult to evaluate the internal consistency.

3.4.3.2 Post-lesson interview with students

A post-lesson interview was also conducted with two students at the same time after each lesson observation. The interview protocol can be found in Appendix 5. Similar to the teacher interviews, the student interviews were also semi-structured.

Question 1 was similar to Question 1 in the post-lesson interview with teachers to understand how well the observed represented the typical classroom interaction behaviour in their lessons. Question 2 required the students to write down two things they learnt in this lesson, and two things they were not clear about (if there were any). They were instructed that these four items could be either about science knowledge or the English language. The purpose was to have a conversation starter and some material for discussing their learning in this lesson. Question 3 aimed to elicit students' views on the teaching behaviours that were helpful for their learning or caused problems in their learning, which could reflect their beliefs about effective science teaching and English teaching.

Question 4 aimed to open up the opportunity for the students to provide any comment or reflection on the learning in general in the lesson. Question 5 focuses on the language aspect in particular, similar to Question 4 in the teacher's post-lesson interview. Students' answers to how they think their teachers helped them tackle the language difficulty could reflect what they believed were effective English teaching in EMI science lessons. Question 6 was designed in response to the parallel CMI classes, similar to Question 6 in the teachers' post-lesson interview. Again, this question was added to understand if this variable made an impact on the students' interaction with the monolingual teachers in the EMI science classes.

All student interviews were conducted in Mandarin as using the students' L1 may help them express their views more freely. To ensure the translation of the interview questions was accurate, all the questions translated into Mandarin were also back translated into English by another researcher to double check if the back translated questions have the same meaning as the original questions in English.

3.4.4 Data collection procedure

The data collection follows the same procedure for every school visited, demonstrated in Figure 2 below.

A typical data collection schedule at a school

1.Arrival at the school

- sent out the hardcopies of the information letters and consent forms to the Principal and teachers, explained the purpose of my visit and answered questions about my research
- arranged the lesson observation schedule with the foreign monolingual science teachers
- sent out the teacher background questionnaire and the teacher beliefs questionnaire to teachers

2. Pre-lesson interview with the teacher

- an audio-recorded interview with the teacher usually right before the lesson observation

3. Lesson observations of two lessons per teacher

- handed out the information letter and opt-out form to the students, explained the purpose of my visit to the students, and answered questions about my research
- naturalistic observation and video-recording of two lessons per teacher
- sent out the student beliefs questionnaire to the students

4. Post-lesson interviews with the teacher and two students

- an audio-recorded interview with the teacher shortly after the lesson observation
- an audio-recorded interview with two students at the same time shortly after the lesson observation

(the same procedure of interviews and lesson observation took place again for the second lesson observed)

5. A general interview with the teacher

- an audio-recorded general interview with the teacher after the two lesson observations were completed

6. Collecting back all questionnaires

Figure 2 a typical schedule of data collection at a school

Before the lesson observations, the teachers were explicitly asked to select two consecutive lessons that could reasonably represent their ordinary lesson designs for me to observe. During the lesson observations, a camera was placed at the back of the classroom. Notes were also taken during the lessons regarding the important behaviours in teaching subject matter and English, using the lesson observation note-taking sheet (see Appendix 6). This helped me to keep my memory fresh for the post-lesson interviews. What is often discussed in the literature about having the researcher in the classroom and having the lesson recorded is the observer effect (Lo, 2010). This means that while an observer, or a camera is present in the classroom, the teacher and students may change their ordinary behaviour. This could undermine the validity of the data for a naturalistic observation design. To examine if there was an observer effect, in the post-lesson interviews the teachers and students were asked if they felt their behaviour in the lesson was different from their normal lessons. For all the 30 lessons, the teachers and students in their separate interviews confirmed that lesson was conducted as usual. Consent of video-taping was obtained from both the teacher and the students in each class. Ethical considerations are elaborated in Section 3.8 later.

As mentioned in Section 3.2.3.4, the student questionnaires came from two groups of students. Group 2 did not participate in the lesson observations. However, the questionnaires were distributed to Group 2 by me in person as well. Regarding the post-lesson interview with students, the teacher was asked to select two students of an average level of academic attainment and English proficiency. This was to ensure that the two students interviewed could to a reasonable degree reflect the experience of the majority of the class. Both of the two students in each interview were asked to respond to all the questions in the interview protocol, so they both had the chance to give their answers. They were also instructed to respond to each other's answers.

Although, as explained in Section 3.3 Pilot study, individual interviews with two to three students independently were considered the most effective for eliciting rich answers, in the main study it was found very difficult to find enough time to interview individual students separately while they still had a fresh memory of the lesson. Interviewing only one single student would also be

too limited in understanding the experience of the majority of the students. Thus, a compromise was made to interview two students together at the same time.

The pre-lesson interviews with the teachers were mostly about 10-15 minutes long and the post-lesson teacher interviews usually lasted for approximately 20-30 minutes. The general interview with teachers were about 30-40 minutes. The post-lesson student interviews were approximately 20-30 minutes long. All of the interviews were audio recorded with the teachers' and students' consent. The interviews with teachers and students were conducted in a separate room where there were no other people around, whenever it was possible, as feedback from the polit study suggested. This was to make sure teachers and students could freely express their views.

In summary, the data collected include 30 video-recorded science lessons taught by 15 monolingual EMI teachers, 30 pre-lesson teacher interviews, 30 post-lesson teacher interviews and 30 post-lesson student interviews that went with the lesson observations, and 15 general teacher interviews. 15 teacher background questionnaire and 15 teacher beliefs questionnaire were collected. 331student questionnaires was collected with a return rate of 73%, which is a satisfactory rate and ensures the questionnaires collected to a fair extent represent the students who were reached out to (Robson, 2002).

3.5 Data analysis for Research Question 1- classroom interaction

The lesson observations, questionnaires and the interviews provided different sources of data to understand the teaching and learning of science and English in these EMI science classes taught by monolingual teachers. It was decided that the analysis of the classroom interaction in the 30 video-recorded lessons was conducted first, followed by the analysis of interview and questionnaire data. The reason of analysing the lessons first was to try to eliminate any possible biases that could arise from other sources of data in understanding the teacher-student interaction, such as teachers' and students' comments from the interviews, the teachers' and students' background and so on. This way the analysis of the lessons could be as objective as possible.

All the lesson video recordings were first transcribed. Then, the transcripts were coded to identify the behaviours of the following 12 parameters - 1) the breakdown of lessons (e.g., the time proportion of different instructional activities); 2). the time length and proportion of teacher-whole class interaction; 3). the time length and proportion of teacher talk and student talk; 4) teacher and student turn taking behaviour; 5). wait time (i.e., wait time after teacher initiations, wait time after student responses); 6). teacher monologue; 7). teacher nomination; 8). the noun verb ratio of student talk; 9). the use of extended IRF sequences; 10). language focused episode (LFE); 11). teacher questions; 12). student questions. The coding of these 12 parameters provided the basis for quantitative and qualitative analysis.

Section 3.5.1 below details the transcription process of the lessons. Section 3.5.2 explains the coding principles of the lesson transcripts. Section 3.5.3 provides the rationale of the 12 parameters selected for quantitative analysis of the classroom interaction in this study and Section 3.5.4 describes the qualitative analysis of the classroom interaction.

3.5.1 Lesson transcription

As this study focuses on the teacher-whole class verbal interaction, only the whole-class verbal interactions were transcribed. This means the conversations among students themselves and between teachers and individual students were not transcribed. In addition, the non-content related talk which was not related to the teaching of English and science content, such as managing the classroom behaviour and asking students to hand in homework, was not transcribed, either. Examples of non-content talk are given in Appendix 10. This is because the aim of this study is to explore how teachers used interaction to facilitate students' learning of English and science content. The non-content talk is considered not directly addressing these two key issues.

3.5.1.1 Transcription in NVivo

To make sure the transcription of the lesson videos was sufficient and accurate, a set of transcription protocol was strictly followed, as shown in Appendix 11. The transcription was conducted in NVivo 11, which allowed a precise record of the start and end time of each turn. This provided the much-needed support for the quantitative data analysis, which was largely

dependent on the time length of behaviours (e.g. teacher talk, student talk). A screenshot of how the transcription process took place in NVivo is given in Figure 3 below.

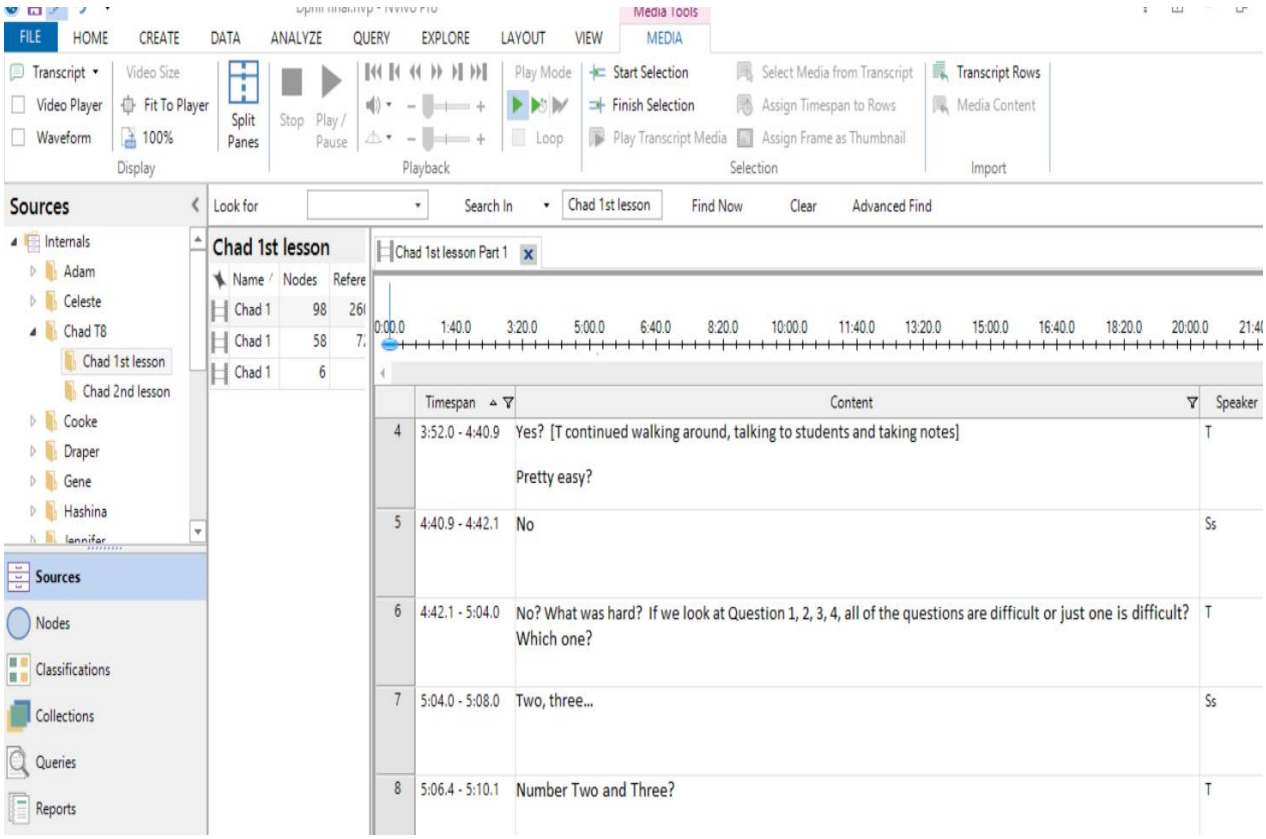


Figure 3 a screenshot of transcription in NVivo

In NVivo, the time point in the timespan column is presented in the format of XX:XX.X. The numbers before and after the colon are minutes and seconds of the lesson. The last digit is mini second, counting from 0-9. For example, in Figure 3 above, the timespan for Turn 4 is 3:52.0 - 4:40.9, which means this turn was from three minutes and 52.0 seconds into the lesson and to four minutes and 40.9 seconds into the lesson.

3.5.1.2 The training process of the research assistants

Out of the 30 lessons, 13 of them were transcribed by me. Due to the time constraints of the project and the sheer number of lessons for transcription, the other 17 lessons were outsourced to research assistants to transcribe. To ensure the transcription was completed to a consistent standard and closely following the transcription protocol, all the research assistants were trained first before starting their transcription.

The ethics requirements were also fulfilled in the outsourcing of the transcription. The teachers of these lessons were contacted first through email to ask for their consent. It was explained that the assistants would be requested to sign a confidentiality form to protect the teachers', students' and schools' privacy. All the teachers, apart from one, replied giving their consent. Thus, the two lessons which were not consented to be transcribed by assistants were transcribed by me, and the other 15 lessons were transcribed by assistants.

After obtaining consent from the teachers, a transcription job advertisement was sent to university students in Hong Kong and Beijing through my personal contacts. The students who responded were sent a confidentiality form to sign (see Appendix 12). Those who returned the form started the training procedure.

The training procedure was conducted through showing the assistants a sample of the transcription done by me (see Appendix 13), explanation of the transcription protocol, and a practice transcription task to ensure they understood the protocol clearly. A short video clip from the lesson sample was selected for this practice task and all assistants were requested to transcribe it closely following the transcription protocol. This was an important step to make sure the common issues and difficulties the assistants faced were noticed and addressed before the real transcription job started. It was also meant to screen the assistants who were not competent enough for the transcription. To ensure these goals were met, the choice of the practice video clip was based on the following criteria: 1) the difficulty of the content knowledge was of an average level among all the lessons collected; 2). the behaviours in the video clip covered most of the requirements in the transcription protocol (e.g. including teacher gesture, emphasis, etc.);

All assistants' transcripts for this practice transcription task were examined in detail and feedback and corrections were provided to each of them through email. Through this practice task, the following common issues were found.

- Some of the emphasis and prolonged words were left unmarked.
- The parts where teachers were doing non-academic talk, which did not need to be transcribed, were transcribed.
- Some pauses were not marked.
- In some cases, wait time was not marked.

- The individual utterances from one speaker spoken at one turn were separated into individual lines in the transcript. This was unnecessary and all the utterances from one turn by a teacher or a student should be put in only one line with the start and end time of this turn given in the timespan column.

The assistants who demonstrated a satisfactory level of accuracy in their transcription were selected to start the transcription job. 11 transcribers were recruited.

3.5.1.3 The checking of the transcripts from research assistants

After receiving the transcripts from each research assistant, I also watched through the lesson video clips and checked the transcripts. The common errors spotted in the transcripts submitted included:

- inaccurate capture of words
- the misuse of 'wait time' when the teachers were taking time to set up PPTs or looking for certain pages in their textbooks.
- inaccurate capture of the start and end time of turns

The errors were corrected by me. All the transcripts received from the assistants were also imported to NVivo for data analysis.

3.5.2 Lesson coding

After the transcription of the 30 lessons was completed, all the lesson transcripts were coded in NVivo. A comprehensive list of all aspects of classroom interaction behaviours that were coded in the 30 lessons is shown in Table 9 below. There were eight categories of coding, which later produced the results of 12 parameters of classroom interaction.

The purpose of the coding was to identify the target behaviours and prepare for the measurement of the time length and proportion, and number of occurrences of these behaviours. This provided quantified descriptions of the classroom interaction. The identification of these target behaviours

also prepared for qualitative analysis of the content of these behaviours. The coding process formed the basis for answering Research Question 1.

Coding framework for lessons		
Categories of classroom interaction coded	Codes	
1.Instructional activities (i.e., the activities outside of the teacher-whole class interaction time)	Students' self-practice, group discussion, students' note taking, video, students' practical work, non-content related.	
2.IRF (Initiation, Response, Feedback)	Examples of the codes include T-I (1), S-R (1), T-F (1), T-I (2), T-I (1) R, etc.	
3.Wait time	WT after T-Is, WT after S-Rs	
4.Teacher monologues	T-monologue	
5.Teacher nominations of individual students to answer questions	T-N	
6.Teachers' explicit teaching of the English language	Language-focused episode (LFE)	
7.Teacher questions	The following are the types of questions, which are also the name of the codes used.	
	1.Pumping	Chin's (2007) framework of constructivist teacher questioning approaches
	2.Reflective toss	
	3.Constructive challenge	
	4.Association of key words and phrases	
	5.Verbal cloze	
	6.Multi-pronged questioning	
	7.Stimulating multimodal thinking	
	8.Focusing and zooming	
	9.Question-based prelude	
	10.Question-based outline	
	11.Question-based summary	
	1.Recall questions	Non-constructivist questions types, emerged after inductive analysis.
	2.Vocabulary check questions	
	3. Direct comprehension check questions	
8.Student questions	1.Memory questions	Gallagher and Aschner's (1963) framework
	2.Convergent thinking questions	
	3.Divergent thinking questions	
	4.Evaluative thinking questions	
	1.Language-related questions	

	2.Procedural questions	Question types emerged after Inductive analysis

Table 10 the coding framework for lessons

Figure 4 below demonstrates how the lesson transcripts were coded in NVivo.

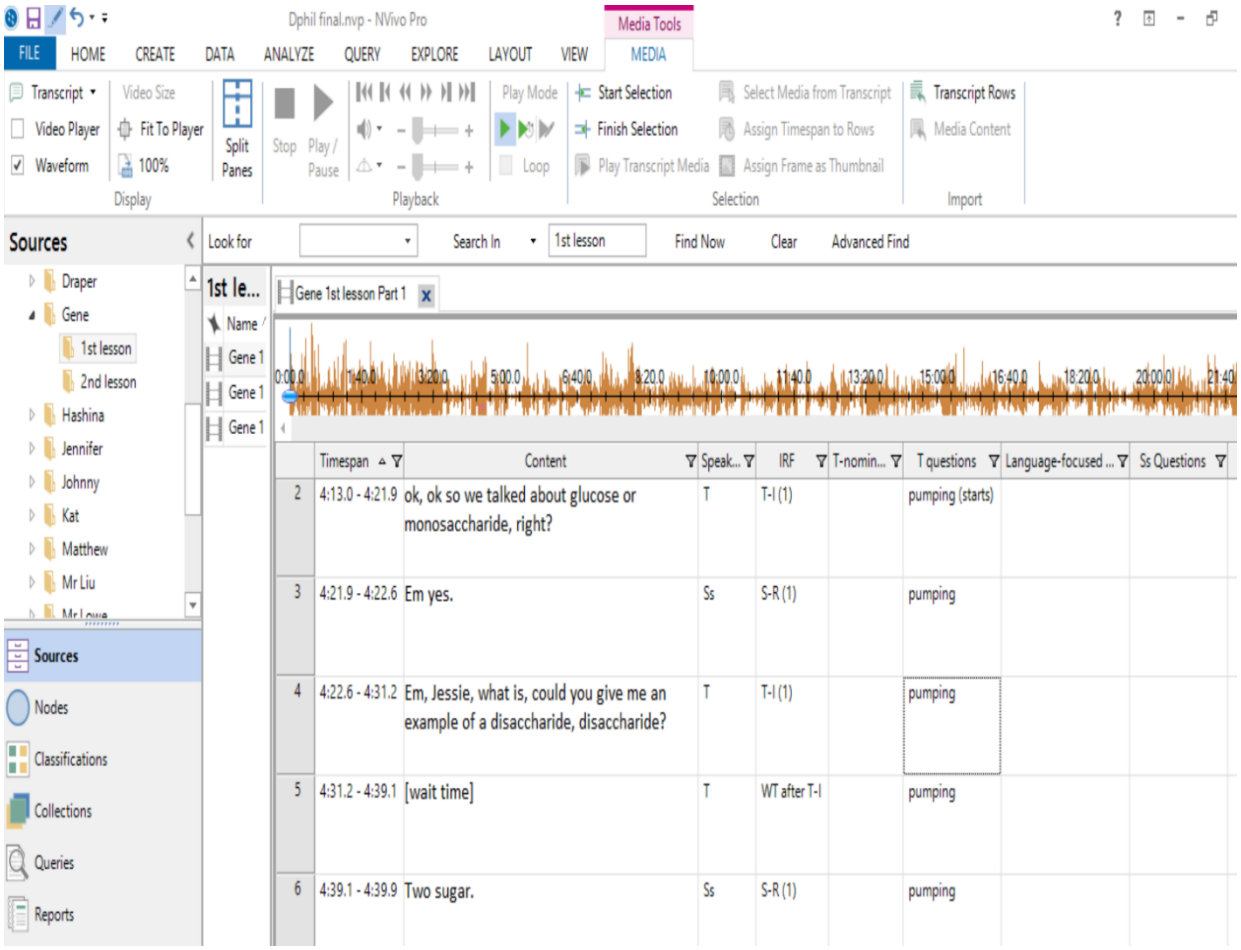


Figure 4 a screenshot of coding in NVivo

Some coding categories were pre-determined because of the widely recognized importance of them in the literature. These coding categories include the use of practical work in the category of different instructional activities, IRF, teacher nomination, wait time, language-focused episodes, teacher and student questions and so on. The rationale for coding these behaviours is elaborated later in Section 3.5.3 Quantitative analysis framework for classroom interaction. Other codes were developed through an iterative and inductive process as common patterns emerged from the data. These codes include teacher monologues, certain types of teacher and

student questions, shown in Table 10 above, certain types of instructional activities, such as students note taking, group discussion, video and so on. As the rules for the coding of these behaviours are lengthy, the sections below focus on only the technical procedures of the coding process. The rationale of identifying these behaviours is given in Section 3.5.3.

3.5.2.1 The coding of IRFs

I, R, F stands for initiation, response and feedback and are terms initiated by Sinclair and Coutland (1975). I-R-F is not a sequence in naturalistic conversations but is a sequence of acts that typically take place in classrooms. As also explained in Chapter 2 Literature Review, it has been commonly used as a data analysis tool for classroom interaction (e.g., Kelly-Hall & Walsh, 2002; Nikula, 2007; Wolfe, 2008; Mercer, 2010; Howe & Abedin, 2013).

The coding of I, R and F provides a basis of identifying and measuring some of the 12 parameters in the analysis framework of classroom interaction, such as the time length and proportion of teacher talk and student talk and turn taking behaviour. Below is a summary of the key principles followed in the coding process of IRFs.

- 'T' or 'S', standing for teacher and student, was always added in front of I, R or F to show the speaker of this act. For example, an initiation from a teacher was coded as T-I, and an initiation from a student was coded as S-I.

- A number was also given in all the codes (e.g., T-I (2)) to show which cycle of an extended IRF sequence this act was at. For example, an initiation from a teacher at the third cycle of an extended IRF sequence was coded as T-I (3).

- 'A', standing for action, was added to the teacher initiation acts where the initiations aimed at eliciting students' actions rather than verbal responses, e.g., T-I (1) A.

- 'R', standing for repetition or reformulation, was added to the teacher initiations where the teacher questions were actually repetitions of the same question asked previously, or reformulations of the same question with linguistic modifications, e.g., T-I (2) R.

These coding principles are exemplified with excerpts from the lessons of this study in Appendix 14.

3.5.2.2 The coding of instructional activities

To show the use of the lesson time outside of the teacher-whole class interaction and provide a background of the overall design of the lessons, the commonly used instructional activities that emerged from the data were coded, such as students' note taking, group discussion, video and so on. The instructional activities that took place within teacher-whole class interaction, such as debates and student presentations, were not coded. This was because the behaviours within teacher-whole class interaction time were the main focus of this study and were explored extensively using various coding frameworks, including IRF, teacher questions, student questions, LFEs and so on.

All the codes used for the category of instructional activities are shown in Table 11 below.

codes for instructional activities outside of teacher-whole class interaction	**explanations**
Students' note taking	As emerged from the data, sometimes a noticeable proportion of the lesson time was dedicated for students taking notes from the PPTs. These periods of lessons were coded as 'students' note taking' in NVivo.
Students' self-practice	As emerged from the data, sometimes the teacher asked the students to do exercise on the textbooks, worksheets and so on. These periods of lesson time were coded as 'students' self-practice'.
Group discussion	Any form of discussion among students themselves were coded as group discussion.
Students' practical work	If the lesson observed happened to be a lab lesson which took place in a lab, the time period where the students were doing their own practical work was coded as 'students' practical work'. If the lesson took place in their ordinary classroom, not in a lab environment, but the students were given certain tools to do experiments, the time period where students were conducting their experiments was also coded as 'students' practical work'.

	If there was verbal interaction between the teachers and the whole class, it was still coded following the same rules of coding as the ones applied to teacher-whole class interaction in non-lab lessons.
Video	As emerged from the data, teachers often showed long clips of videos as part of their teaching. These excerpts were coded as 'video'. As this was not part of teacher-student verbal interaction, the words from the videos were not transcribed.
Non content-related	The time period in a lesson that was not about teaching the academic content, or the language was coded as 'non-content talk'. Non-content talk was not transcribed as it was considered irrelevant to the focus of this research, as explained earlier in Section 3.5.1.

Table 11 the coding framework for instructional activities

These activities were typically conducted without teacher-whole class interaction or only with a minimum amount of it. Although these activities did not directly form part of the classroom interaction, the use of different instructional activities could provide the full picture of how the lesson time was spent overall and provides the background where the classroom interaction was situated within. The use of instructional activities can also reveal certain features of constructivist teaching approach, such as the use of practical activities and group discussion, which were also enquired about in understanding the teachers' and the student beliefs.

3.5.2.3 The coding of wait time

Wait time was also identified as an important aspect of teacher-student interaction to examine and it was coded as well using NVivo in this research. There were two types of wait time that were coded in this study. The first one was wait time after teacher initiations and the second one was wait time after student responses. Table 11 below gives the explanation of the two types of wait time and the codes used.

Types of wait time	Codes
Wait time after a teacher's question between the end of a teacher's question and the onset of a student's response.	Wait time after T-Is

Wait time after a student's response to see if the student or other students want to add more information	Wait time after S-Rs

Table 12 codes for wait time

Where the two types of wait time take place in an IRF cycle is shown in Figure 5 below.

(wait time after T-Is) (wait time after S-Rs)

teacher initiation (T-I) . . . . . student response (S-R) . . . teacher feedback (T-F)

Figure 5 wait time in an IRF cycle

The coding of wait time in NVivo is demonstrated in the screenshot in Figure 6 below.

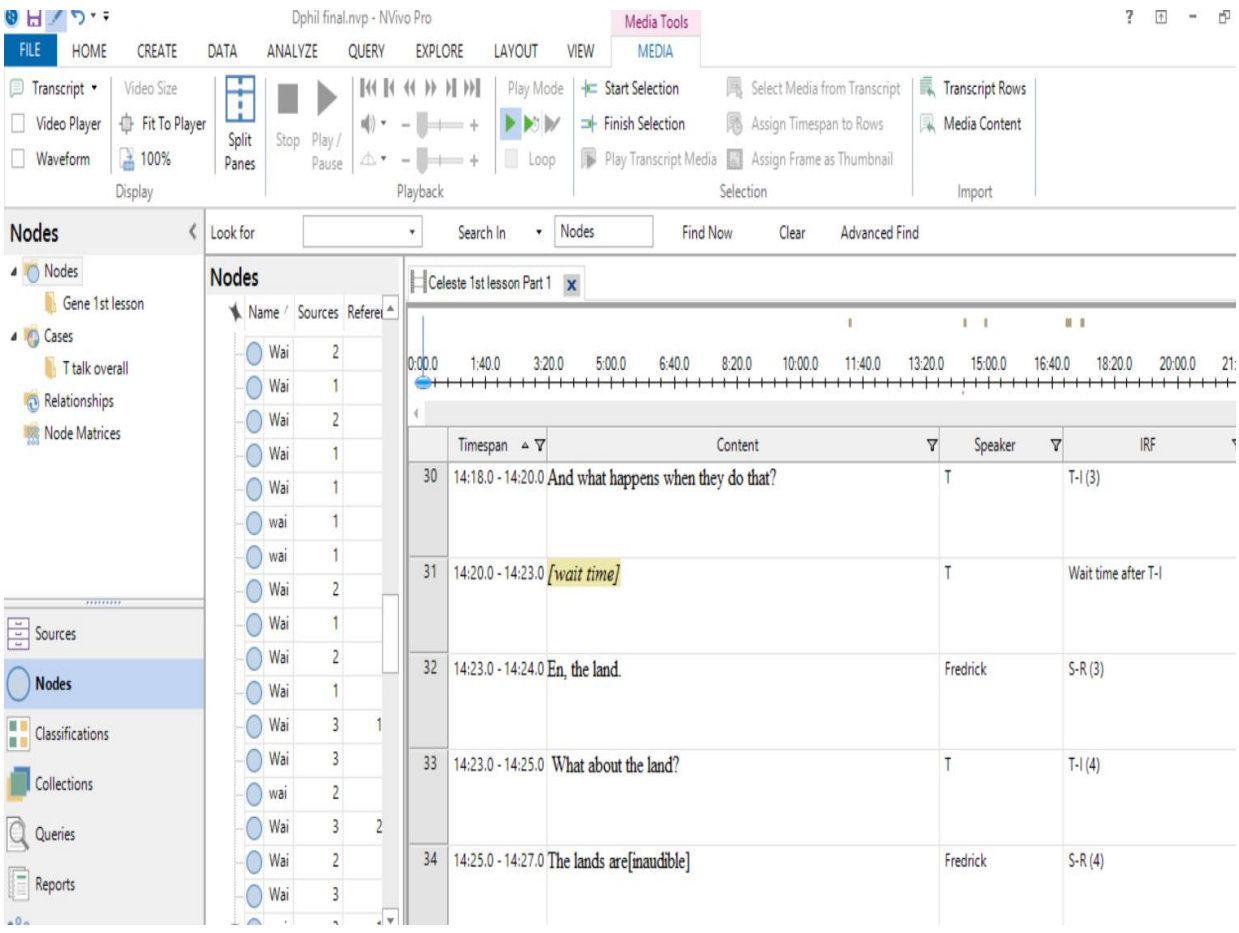


Figure 6 the coding of wait time in NVivo

As can be seen, in Turn 31 in Figure 6 above, the wait time after T-I was also coded in the column

of IRF, the same as the instructional activities. This was also because the use of wait time did not overlap with the acts of I, R and F.

In this study, any wait time that is longer than one second was coded. Wait time that was shorter than one second was considered not sufficient enough to be coded.

3.5.2.4 The coding of teacher monologue

As emerged from the lesson data, during teacher-whole class interactions the teachers often gave monologues without initiating a question to the students. The monologues were independent from IRF exchanges between teachers and students as they were uni-directional lecturing by the teacher and the students were not invited to interact. They were identified as 'T monologue' in NVivo. The purpose was to identify the lengthy monologues teachers gave and separate them from the acts of teacher initiations and teacher feedback. An example is given below.

Excerpt 1

Turn	Timespan	Content	Speaker	IRF
69	18:42.5 - 19:06.9	Yeah, when you play with leaves, in Canada, in the fall, you always play with leaves. You can feel that some are sticky, some are soft. Some are hairy. Some have spikes on them. That's because every leaf is covered in epidermis. [T writing down the word "epidermis" on the board]. So, the epidermis, you also can not see in this picture. But it is the structure that covers the surface of all leaves. And it can be different for each leaf. So, one leaf might be sticky, one leaf might be soft, one leaf might be fuzzy, with little hairs on top, one leaf might have spikes. This is the epidermis. So, a leaf has vascular bundles, a leaf has veins, a leaf has epidermis, and a leaf also has cuticle [T writing "cuticle" on the board, screenshot 17], and this is the structure that covers the epidermis. This structure, protects, or helps the leaf to prevent itself from losing water. So, it helps the leaf to conserve water. So, the cuticle minimizes the loss of water for the plant, for the leaf.	T	**T monologue**
70	21:05.6 -	Why do you think this is an important structure?	T	T-I (1)

	21:08.8			

As can be seen, teacher monologues were coded in the column of IRF. This was because they did not overlap with acts of I, R or F, but were independent from them.

3.5.2.5 The coding of teacher nomination

Teachers' nominations of individual students to answer questions were also coded in this research. The code used was 'T-N'. Below is an example.

Excerpt 2

Turn	Timespan	Content	Speaker	IRF
1	0:01.0 - 0:04.3	Why do complex plants have roots and shoots system?	T	T-I (1)
2	0:04.3 - 0:08.5	[wait time]		wait time after T-I
3	0:08.5 - 0:09.0	Tommy?	T	**T-N (1)**
4	0:08.9 - 0:26.1	Complex plans need root systems to keep them, err, stable, err and not fall when wind blows and they have, err shoot system so that they can get energy, like sunshine.	S	S-R (1)
5	0:26.1 - 0:47.4	Very good! So, one thing we could look at is that plans need root systems to be stable so that they are not blown away. They are rooted or anchored in one spot. Shoot systems, to get energy. They are the parts that grow above the ground, the stem.	T	T-F (1)
6	0:45.0 - 0:47.4	Is there anything else we can add to that?	T	T-I (2)
7	0:47.3 - 0:49.6	[wait time]		wait time after T-I
8	0:49.0 - 0:49.6	Carrie?	T	**T-N (2)**
9	0:49.6 - 0:55.0	Err, err, root system also helps plants to store water and nutrients.	S	S-R (2)
10	0:55.3 - 1:03.6	Good! So, the root system, not only does it anchor plants but it also helps the plant to store water and nutrients.	T	T-F (2)

11	1:03.6 - 1:07.0	Kevin?	T	**T-N (3)**
12	1:07.6 - 1:31.5	Err, complex plants need to actually absorb energy from the sun and car, carbon dioxide from the air so they need to develop root system and they need much water and nutrients underground to develop shoot system.	S	S-R (3)
13	1:31.5 - 1:33.7	So what system did you, [T went to look at Kevin's notebook]	T	T-I (4)
14	1:33.7 - 1:37.7	This is root, root system.	S	S-R (4)
15	1:37.7 - 1:39.1	Right, you switched them around.	T	T-F (4)

As shown above, Turn 3 was coded as 'T-N (1)' to identify this was the teacher nominating a particular student to answer. A number was also included to show which cycle of IRF it was in. In this case, T-N (1) means the teacher nomination was in the first cycle of this IRF sequence, and later on T-N (2) in Turn 8 means the teacher nomination was in the second cycle. The same applied to T-N (3) in Turn 11. Both T-N (2) and T-N (3) were follow-ups of the teacher' initiation T-I (2) in Turn 6 '*Is there anything we can add to that*? ' .

3.5.2.6 The coding of Language-focused episodes (LFEs)

Another important aspect of teacher-student interaction coded was teachers' explicit teaching of language structures. They were coded as a *language-focused episode.* The purpose was to mark the components of teacher-whole class interaction where students' attention was deliberately diverted from the science plane to the language plane. The types of LFEs were also coded according to the linguistic aspect addressed in an inductive manner as the types of linguistic features instructed on emerged from the data.

An example of LEFs is as follows.

Excerpt 3

Turn	Timespan	Content	Speaker	LFEs
13	14:30.02-15:11.03	Converging is like this and diverging is the opposite. [T using gesture] So, parallel, lens through which parallel, err, light rays, that's the same, parallel rays, err, in this case, diverge, not converge, diverge. **That means they go apart. Converge means coming together. Diverge**	T	**Language-focused episode**

		means they go apart. [T using gesture to show "converging" and "diverging"] So diverge, err, what it says, after, after, err refraction through lens. OK?		**(Vocabulary-focused)**

As it shows above, Excerpt 3 included the teacher's explicit attention on explaining the key vocabulary '*converging*' and '*diverging*' and thus was coded as a 'language-focused episode'. As the linguistic feature instructed on is vocabulary, this LFE was also coded as 'vocabulary-focused'. LFE was coded in its own column, separate from the column of IRF. This was because the LFEs could involve acts of I, R or F, and to make the coding clearer, a different column was assigned to them.

Only periods of explicit teaching of English in this research was coded as 'language-focused episodes' and thus the implicit language learning opportunities were not coded. For example, when a teacher paraphrased a student's answer into the target language form, or required a student to clarify his/her answers during incidents of negotiation of meaning without explicit explanation of language forms, students' attention could still be diverted to the language and language acquisition could also take place (Long, 1985). However, these episodes with implicit focus on language were not coded in this study.

3.5.2.7 The coding of teacher questions

The coding framework of teacher questions, as shown in Table 13 below, consists of a previously established framework , i.e., Chin's (2007) framework, representing the constructivist teacher questions, and the development of three types of non-constructivist teacher questions based on the data of this study. A justification of the selection of Chin's (2007) framework is provided first in Section 3.5.2.7.1, with examples from the lesson excerpts of this study given in Appendix 15 to demonstrate the coding process. Then, the development of the non-constructivist question types is explained in Section 3.5.2.7.2, with examples given in Appendix 16.

Coding framework for teacher questions	The following are the types of questions, which are also the name of the codes used in the coding process of the classroom data.	
	1.Pumping	Chin's (2007) framework of constructivist questioning-based approaches.
	2.Reflective toss	
	3.Constructive challenge	
	4.Association of key words and phrases	
	5.Verbal cloze	
	6.Multi-pronged questioning	
	7.Stimulating multimodal thinking	
	8.Focusing and zooming	
	9.Question-based prelude	
	10.Question-based outline	
	11.Question-based summary	
	1.Recall questions	Non-constructivist question types emerged through inductive analysis.
	2.Vocabulary check questions	
	3.Direct comprehension check questions	

Table 13 the coding framework for teacher questions

3.5.2.7.1 Justification of the selection of Chin's (2007) framework

The exploration of the commonly used frameworks for teacher questions in the previous literature produced Table 14 below.

Studies	Age	Country	Setting	Aim of the framework	The framework
Bloom et al. (1956)				To identify educational objectives	knowledge, comprehension, application, analysis, synthesis, and evaluation.
Gallagher & Aschner (1963)	junior high school level	the U.S.	classes of gifted students	To investigate productive thought processes in gifted students through examining teacher and student questions	1).Cognitive memory questions 2).Convergent thinking questions 3). Divergent thinking questions 4). Evaluative thinking questions
Yip (2004)	secondary school	Hong Kong	EMI science classes	To explore how teacher questions facilitate conceptual change	1). Questions to explore students' pre-conceptions 2).Questions to challenge students' misconceptions and present the conflicts between misconceptions and the scientific ideas 3). Questions that lead students to resolve the conflicts and making sense of the new scientific ideas 4). Questions that help students apply the new scientific concepts in other situations.
Dalton-Puffer (2007)	secondary school	Austria	CLIL classes	To analyse the goal of teacher questions in CLIL classes	1). Questions for facts 2). Questions for explanations 3). Questions for reasons 3). Questions for opinions 4). Metacognitive questions
Watts & Alsop (1995)	Primary school	US	Science classes	To analyse the types of teacher questions	1). Instructional (e.g. 'Can you see what is supposed to happen?'),

					2). Conceptual ('Can you understand the difference?') 3).Transactional questions ('Has everybody finished that piece of work?')
Chin (2007)	secondary school	Singapore	science classes	To analyse how teacher questions are used as classroom discourse strategies to promote students' productive thinking, underpinned by the socio-constructivist perspective.	1).Socratic questioning 2).Verbal jigsaw 3).Semantic tapestry 4).Focusing and framing All together there are 11 categories under these four main domains.

Table 14 review of the literature on teacher question frameworks

In the selection of teacher question framework in this research, Chin's (2007) framework was considered the most appropriate for this study. Bloom's (1956) taxonomy, although has been widely used, is a rather general framework and was not specifically designed in the science learning context or in an L2 instructional context. Yip's (2004) study was conducted in L2 EMI context and his framework of conceptual change also adopted the constructivist view of science teaching. However, this framework did not reflect the L2 students' language needs in categorizing science teachers' questions. This framework was also specifically designed to focus on the process of how teachers induce conceptual change in their students, which is considered a key process of science learning from the viewpoint of constructivism (Ertmer & Newby, 1993). However, this framework may not be comprehensive enough to capture other learning opportunities in science classes, which are embedded within the interaction process. Dalton-puffer's (2007) framework, although was developed in the CLIL context, which is similar to the context of this study, was not tailor made for CLIL science classes. Gallagher & Aschner's (1963) framework and Watts and Alsop's (1995) framework were all considered not detailed enough to enable a fine-grained analysis of the teacher questions in this study.

Chin's (2007) framework, as mentioned in Section 2.3.4.2 in Chapter 2 Literature Review, was developed based on the social constructivist framework. It drew upon 36 video-recorded Grade 7 science lessons by six teachers from four schools in Singapore. Questions were analysed to examine how they advanced students' conceptual thinking, as demonstrated in students' verbal output, and how teachers' follow-up questions were built upon students' answers. Based on the types of constructivist thinking that were encouraged in students, four domains of constructivist questioning-based approaches were identified, embedded within the classroom discourse as discursive strategies. These four domains of questioning approaches are: *Socratic questioning, verbal jigsaw, semantic tapestry, focusing and framing.* In each domain, there are sub-types of questions. Table 15 below provides a brief explanation of these question approaches.

Type of questioning approaches	Functions	Sub-types
1.*Socratic questioning*	Prompt and elicit information from the students and guide their	*Pumping* is used when the teacher asks for more information from students and foster

	thinking rather than directly transmitting knowledge to them.	students' talk rather than giving away the answer directly. *Reflective toss* is used when students ask a question but the teacher responds also with a question to lead students to find out the answer themselves. *Constructive challenge* is used when students provide an incorrect answer the teacher respond with a question to lead students to realize their misconceptions.
2.*Verbal jigsaw*	Consolidate students' linguistic knowledge of science terminology to form declarative statements	*Association of key words and phrases* serves to elicit key scientific vocabulary from students for the formulation of declarative knowledge and build up a mental framework, especially when there is a high number of technical terms involved. *Verbal cloze* takes place in the form where teachers leave out blanks in their sentences for students to fill in.
3.*Semantic tapestry*	Help students construct cohesive understandings of concepts where there is not a high concentration of technical terms	*Multi-pronged questioning* is used when teachers ask students to approach one issue from different angles and aspects, for example, through processing information in textual descriptions and in drawings, and actively producing verbal explanations and drawings. *Stimulating multimodal thinking* approach is used when students are asked to switch between a variety of modes of thinking, for example, through visual images, linguistics or symbolic resources or formulas, to solve a problem. *Framing & zooming* is used when the teacher adjusts the nature of the questions depending on the kind of thinking to be elicited in the students, e.g., at the macro/observational level or micro/molecular level. The questions are often switched between broader views and more local and specific questions.
4.*Framing*	Use questions to frame a problem to structure the discussion. This is often used when factual,	*Question-based prelude* is used as an expository preface to help students see the structure of the information introduced subsequently.

	descriptive or sequential information is sought after.	*Question-based outlines* is used when an overarching question is asked, and the teacher provide a set of outline sub-questions to break down the whole thinking process into smaller steps. These questions are often presented visually. *Question-based summary* is used as a summary in a brief question-and-answer format to reinforce the key concepts

Table 15 Chin's (2007) framework

Chin's framework was considered the most appropriate framework for this study because of four considerations. First, the theoretical foundation in Chin's framework aligns with the theoretical foundation and the purpose of this study, i.e., social constructivism and how teachers use questions to guide students' conceptual development in the lens of the constructivist teaching framework. Second, Chin's framework adopted the perspective of examining the whole teacher-student dialogues to understand how teacher questions promote students' productive thinking. As Chin argued, teachers' use of questions was seen as part of the teacher-student exchange and student responses served as evidence in understanding the function of teachers' questions. This also aligns with the focus of this current research, which aims to explore how teacher-student verbal interaction overall facilitates the learning of science and English. The third reason is the inclusion of the *verbal jigsaw* approach, which specifically tackles the challenge of a high quantity of science terminologies, which could be an important issue for the EMI students in this study. Lastly, Chin's framework is a rather detailed taxonomy and thus allows the analysis of a wide range of teacher question types in this study. It was also developed based on sufficient empirical data.

Examples from this study coded by Chin's (2007) framework are given in Appendix 15.

3.5.2.7.2 The development of non-constructivist teacher question types

Section 3.5.2.7.1 above elaborated on Chin's (2007) framework for coding the constructivist teacher questions in this study. However, there were also non-constructivist teacher questions,

which were not used to promote productive and higher-order thinking. Three frequently used types of non-constructivist questions emerged - *recall questions, vocabulary check questions,* and *direct comprehension check questions*.

3.5.2.7.2.1 Recall questions

Recall questions were used to ask students to retrieve information they had learnt before about science concepts, explanations of processes and so on.

An important factor in coding recall questions was the context where the question took place. For example, although some questions may seem to be *pumping* under 'Socratic questioning' in Chin's framework, what was being asked about was actually already taught and the real purpose of these questions were reviewing past knowledge. In this situation, these questions were coded as '*recall questions*' rather than '*pumping*'. Two examples are given in Appendix 16.

3.5.2.7.2.2 Vocabulary check questions

The second type of non-constructivist question types that emerged from the data is *vocabulary check questions*. They were employed to check students' understanding of individual vocabulary in a straightforward manner, usually in the form of '*do you understand this word?*', or '*do you know the meaning of this word?*'. They are different from the *association of key words and phrases* approach in Chin's (2007) framework because they were not used to fulfil the aim of helping consolidate students' linguistics knowledge of various key science terminologies and produce coherent statements to build a mental framework of the high number of science terminologies. Thus, *vocabulary check questions* focus on individual vocabulary and switch students' attention from the content to language. In comparison, *association of key words and phrases* approach is meant to still maintain on the science content plane. The latter usually requires the students to produce the target vocabulary themselves while in *vocabulary check questions* the target vocabulary was usually uttered by the teacher.

3.5.2.7.2.3 Direct comprehension check questions

Another commonly used type of teacher questions that emerged from the data is '*direct comprehension check questions*', where teachers asked directly if students understood or had any questions. An example is also given in Appendix 16.

3.5.2.8 The coding of student questions

This section explains the coding framework used for student questions in this study, as shown in Table 16 below. Examples from the lessons of this study are provided in Appendix 17 and Appendix 18.

Coding framework for student questions	1.Memory questions	Gallagher and Aschner's (1963) framework
	2.Convergent thinking questions	
	3.Divergent thinking questions	
	4.Evaluative thinking questions	
	1.Language-related questions	Question types emerged after inductive analysis
	2.Procedural questions	

Table 16 the coding framework for student questions

3.5.2.8.1 Justification of the selection of Gallagher & Aschner's (1963) framework

The following commonly cited frameworks were consulted in the selection of a framework for student questions.

Studies	Age	Country	Setting	Aim of the framework	The framework
Chin & Chia (2006)	Year 9	Singapore	project group work	To investigate the sources of inspiration for students' questions and how these questions guided the students in knowledge construction when carrying out biology project work in problem-based learning	(1) information-gathering questions (2) bridging questions (3) extension questions (4) reflective questions
Graesser & Person (2016)	College students and Year 7	the U.S.	Tutoring setting with a small number of students	To classify student questions based on the content information sought after, the question-generation mechanism, and the degree of specification.	1) short answer; 2). Long answer; 3). assertion; 4). request/directive All together 18 types of questions under these four broad categories
Chin & Brown (2002)	Grade 8	the U.S.	Small-group setting in lab lessons	To investigate the relationship between students' question types and their learning approaches	1). Text-based 2). Knowledge-based -basic information questions -Wonderment questions
Pizzini & Shepardson (1991)	Grade 5-8	the US	Lab lessons	To compare the quantity and quality of students' questions in problem-solving instruction versus teacher-directed lab instruction.	1).input 2).processing 3).output
Watts et al. (1997)	Primary school and secondary school level	the UK	Whole-class setting	To describe the distinct periods in the process of conceptual change,	1). Consolidation questions 2). Exploration questions 3). Elaboration questions

				manifested by student questions	
Marbach-Ad & Sokolove (2000)	University level	the U.S.	Lectures and small groups	To help university biology students recognise good questions and to explain what types of questions were considered to be high level	(a) questions that do not make logical or grammatical sense or are based on a misunderstanding; (b) questions that are about definition, concept, or facts (c) questions that involve students using information beyond that given in the textbook (d) questions that involve students using higher-level thinking skills
Gallagher & Aschner (1963)	junior high school level	the U.S.	Classes of gifted students	To investigate productive thought processes in gifted students through examining teacher and student questions	1). Cognitive memory questions 2). Convergent thinking questions 3). Divergent thinking questions 4). Evaluative thinking questions
Ciardiello (1998) (applying Gallagher and Aschner (1963)'s framework)	Secondary school level	the U.S.	Non-lab ordinary classrooms	To develop a training program that teachers can use to facilitate students to ask questions	1). Cognitive memory questions 2). Convergent thinking questions 3). Divergent thinking questions 4). Evaluative thinking questions

Table 17 review of the literature on student question frameworks

While evaluating the suitability of these frameworks, Gallagher and Aschner's (1963) framework was considered the most appropriate for this study. Chin and Brown's (2002) framework has only two broad categories, i.e., basic questions and wonderment question. The use of one category, wonderment question, to represent all the questions that require higher level thinking, was also considered inadequate to examine the constructivist nature of teaching and learning in this research. Watts, Gould, and Alsop's (1997) framework provides more detailed specifications of the types of student questions during students' conceptual change process, which is a meaningful stage of learning from the constructivist view (Palmer, 2005). However, the classification was made primarily based on a small pool of teachers and their retrospective account, without evidence of the actual teacher-student interaction. Chin and Chia's (2006) and Pizzini and Shepardson's (1991) frameworks were developed based on lab lessons. Thus, the student question types identified are likely to be very different from the types in this research. Marbach-Ad and Sokolove's (2000) framework was developed at the university level. The 18-category classification proposed in Graesser and Person's (1994) study was considered too detailed for the low number of student questions in this research (i.e., 2.4 student questions on average in a lesson).

Based on the considerations above and the fact that no framework of student questions seemed to have been developed in the EMI science contexts, it was decided that Gallagher and Aschner's (1963) framework is the most appropriate for this research.

Table 18 below provides an explanation of Gallagher and Aschner's (1963) framework.

Type of questions	Thought process required	Signal words &Examples	Cognitive operations	Level of thinking required
1).*Cognitive memory questions*	reproduce facts or other content through the use of such processes as recognition, rote memory, and selective recall.	who, what, where, when e.g., What is energy?	naming, defining, identifying, designating, yes or now responses	lowest
2*).Convergent thinking questions*	Analyse and integrate facts or given information through a structured process to generate new information that leads	why, how, in what ways? e.g., Could you summarize for us	explaining, summarizing, stating relationships, comparing and contrasting	

	to the correct or conventionally accepted answer. Given or known information usually determines the correct response.	the author's major point?		
3).*Divergent thinking questions*	generate his or her own data independently in a data-poor situation, or to take a new perspective on a given topic. Divergent questions have more than one right answer.	imagine, suppose, predict, if…then…, How might…. Can you create…, What are some possible consequences… e.g., How would the U.S be different if it had lost the American Revolution?	predicting, hypothesizing, inferring, reconstructing	highest
4).*Evaluative thinking questions*	require the student to make value judgements and decisions regarding the goodness, correctness, or adequacy of information, based on a criteria usually set by the students.	defend, judge, justify/what do you think, What is your opinion…? e.g., Do you think this is the best solution? Why?	valuing, judging, defending, justifying choices	

Table 18 Gallagher and Aschner's (1963) framework of student questions

Although Gallagher and Aschner's (1963) framework was initially developed to categorize either teacher generated or student generated questions, Ciardiello (1998) took on this framework and developed an instruction program to help secondary school teachers train their students to ask different types of questions. This practice demonstrates the particular suitability of Gallagher and Aschner's (1963) framework for analysing student questions. A close look at the student questions in this study also shows most of them can be captured by this framework, including even the ones that occurred in atypical teaching activities, e.g., the student questions in the whole-class debate in Nicolas's first Biology lesson. Thus, Gallagher and Aschner's (1963) framework can provide detailed enough and comprehensive analysis of the student questions in this research.

Examples from this study coded by Gallagher and Aschner's (1963) framework can be found in Appendix 17.

3.5.2.8.2 The development of two new student question types

Apart from Gallagher and Aschner's (1963) framework, two other types of questions emerged from the 30 lessons in this study which were used frequently. They were 1). *language-related questions*, i.e., the student questions that enquired about the English language or demonstrated their difficulties with the language, which would mostly likely initiate negotiation of meaning with the teacher; and 2). *procedural questions*, i.e., the student questions about procedures to complete tasks.

Language-related questions were particularly relevant to the context of EMI science classes. This type of questions could reflect the EMI science students' language needs, a key issue elaborated on in Section 2.3.4.4 in Chapter 2 Literature Review. As for the *procedural questions*, although they do not necessarily relate to the science content or English, capturing them would be helpful in understanding the nature of the low number of student questions in this study.

Examples of these two types of student questions can be found in Appendix 18.

3.5.2.9 Coding reliability

Following the coding framework explained, all the 30 lessons were coded using NVivo by me. To ensure the coding was accurate and thus leads to reliable results of the lesson data, intra-rater reliability was used as a measurement to address this issue. Inter-rater reliability would also be very helpful to ensure coding reliability. However, it was not feasible as the resources of this PhD project did not allow the employment of another rater.

10% of the lessons (i.e., 3 lessons) were randomly selected to be coded again by me, following the same coding framework, more than six months after the lessons were first coded. This resulted in an intra-rater reliability of 0.80, indicating a reasonable level of reliability of the coding of the 30 lessons in this study (Landis & Koch, 1977; Robson, 2002)

3.5.3 Quantitative analysis framework for classroom interaction

The sections above explained the coding framework of the classroom interaction in this research. The coding provided the basis for the analysis of classroom interaction. As classroom interaction behaviour is a complex matter and to understand it requires the evidence of different aspects of it, 12 parameters of classroom interaction were identified for analysis.

1. The breakdown of lessons (e.g., the time proportion of different instructional activities)
2. Teacher-whole class interaction time
3. Time length and proportion of teacher talk and student talk
4. Teacher and student turn taking behavior
5. Wait time (e.g., wait time after teacher initiations, wait time after student responses)
6. Teacher monologue
7. Teacher nomination
8. The noun verb ratio of student talk
9. The use of extended IRF sequences
10. Language focused episode (LFE)
11. Teacher questions
12. Student questions

Based on the codes that were marked in NVivo, typically the time duration and proportion, and number of occurrences were calculated of the parameters above. The justifications for selecting these parameters to understand teacher-student interaction and methods of measurement are provided in the following sections. Figure 7 below presents an overview of the quantitative analysis framework for the teacher-student interaction.

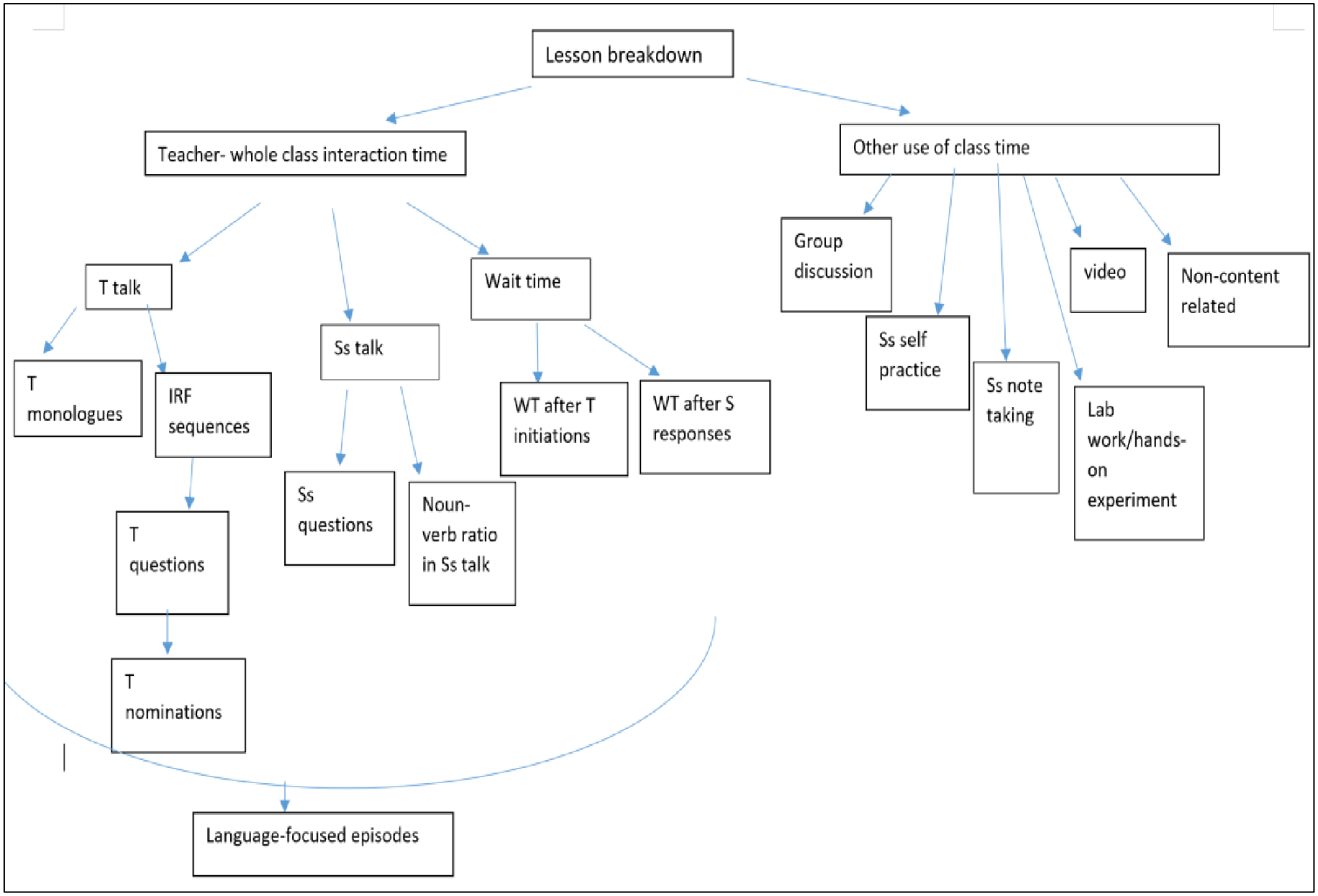

Lesson breakdown
Teacher- whole class interaction time
Other use of class time
T talk
Ss talk
Wait time
Group discussion
Ss self practice
Ss note taking
video
Non-content related
T monologues
IRF sequences
Ss questions
Noun-verb ratio in Ss talk
WT after T initiations
WT after S responses
Lab work/hands-on experiment
T questions
T nominations
Language-focused episodes

Figure 7 an overview of the quantitative analysis framework for classroom interaction

3.5.3.1 Breakdown of lessons

As shown in Figure 7 above, the breakdown of lessons examines the time length and proportion of different instructional activities, particularly the ones that were outside of teacher-whole class interaction time (e.g., students' note taking). This provides an overall picture of how the lessons were structured. The usage of each instructional activities could also reveal the degree of the constructivist nature of these lessons. For example, heavy use of practical activities or group discussion could be considered as an indicator of a constructivist teaching approach (Kang & Wallace, 2005), although this also depends on how the practical activities are used (Abrahams, 2011).

As explained earlier in Section 3.5.2, all the common instructional activities that emerged from the lesson data were added to the list of codes for the breakdown of lessons. The measurement of all the instructional activities was conducted through identifying the codes that represented these activities in NVivo and NVivo produced the time proportion of these codes to the whole lesson time.

3.5.3.2 Teacher-whole class interaction time

The measurement of teacher-whole class interaction time was conducted through adding up the time length of teacher talk, student talk and wait time. Teacher talk was represented by all the codes that started with 'T', e.g., T-I (number) and T-F (number) in IRFs, T-monologue (teacher monologue) and T-N (teacher nomination). Student talk was represented by the codes in IRFs which started with 'S'. Wait time was represented by the codes of wait time after T-Is (teacher initiations) and wait time after S-Rs (student responses).

Table 19 below provided an illustration.

Teacher-whole class interaction time	components	codes included
	1.Teacher talk time	T-I (number), T-R (number), T-F (number), T monologue, T-N.
	2.Student talk time	S-I (number), S-R (number)
	3.Wait time	Wait time after T-I, wait time after S-R

Table 19 components of teacher-whole class interaction time

The data analysis process was also completed in NVivo.

3.5.3.3 Time length and time proportion of teacher talk and student talk

The calculation of the time length and proportion of teacher talk and student talk to the overall interaction time was also completed in the calculation of teacher-whole class interaction time, as explained above.

The reason for examining teacher talk and student talk was that the amount of teacher talk and student talk is a key indicator of the degree of interaction of a lesson. A sufficient amount of student talk is also an important feature of a more dialogic and constructivist science class (Alexander, 2004). Similarly, the important role of student output has also been highlighted in the Interaction Hypothesis in that students' own production of the L2 is necessary for L2 acquisition to take place (Long, 1985), as illustrated in Chapter 2.

3.5.3.4 Teacher and student turn taking behavior

While the time length and proportion of teacher and student talk show the overall weight of teacher and student talk, teachers' and students' turn taking behavior can inform the frequency of exchanges and how long a teacher or a student speaks each time. As mentioned earlier in Chapter 2 Literature Review, Macaro, Granham & Woore (2016) argued that substantial student turns is a key indicator of the quality of teacher-student interaction in L2 classrooms.

Based on the coding framework in this study, a turn could be coded as either an I (initiation), R (response), F (feedback), T monologue (teacher monologue), or T nomination (teacher nomination). While in the previous literature the definition of a turn for the I or F act is rather straightforward, and it is usually the start of the utterance until the end of it, the definition of an R turn can vary. For example, Macaro and Mutton's (2002) study, which explored modern language student teachers' professional development, also analyzed student teachers' turn taking behavior to understand the development of their' interactional patterns with students. In this study, a student's turn of R in an IRF cycle was defined as the time length starting from the end of a teachers' question to the onset of a teacher's feedback, thus incuding possible wait time before and after the students' actual verbal response. This definition of a student R turn in Macaro & Mutton's (2002) is visualized in Figure 8 below.

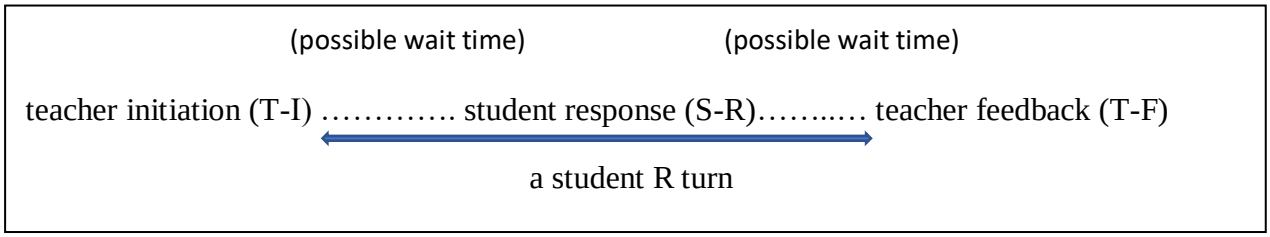


Figure 8 a turn of a student's response in Macaro & Mutton's (2002) study

The rationale for including the possible wait time in the students' turn of a response in Macaro and Mutton's (2002) study, as shown above, is that the floor of speaking is already handed to the student once the teacher finishes his or her question, and during the possible wait time after the teacher initiation the student already started thinking about his or her answer. Similarly, the possible wait time after the student response could be seen as the student is still holding the floor and may be thinking about adding more information. In this current study, however, a student's turn of response is defined as only including the student's actual verbal response, excluding the possible wait time before and after S-R. This definition used in this study is shown in Figure 9 below.

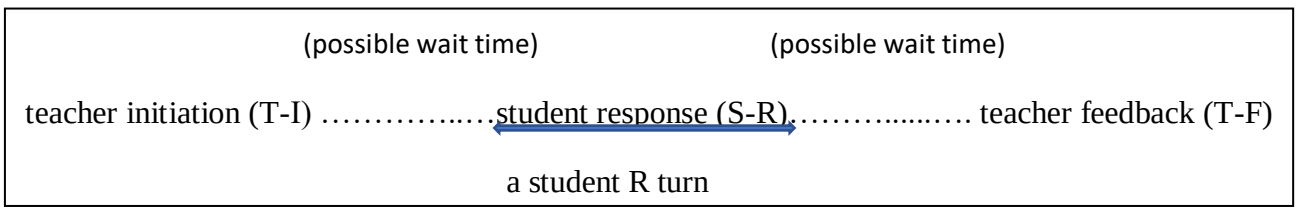


Figure 9 a turn of a student's response in this study

The rationale of teasing out the wait time in this current study was to allow the examination of the teachers' use of wait time in their EMI classes. The purpose was to focus on the teachers' practice with references to how it facilitated students' learning of science and English, and the use of wait time has been argued in the literature as having significant value for learning, which will be explained in the next section.

Based on the definition of a turn above, all codes starting with T were identified in NVivo to show all the teacher turns and all codes starting with S were identified to show all the student turns. NVivo showed the total numbers of teacher turns and student turns in each lesson. The mean turn length of a teacher/student turn in each lesson was obatined through dividing the total time length of all teacher/student turns in this lesson by the total number of teacher/student turns in this lesson.

3.5.3.5 Wait time

Wait time is the third component of the teacher-whole class interaction time examined, after teacher talk and student talk. Tobin (1987) stated that sufficient wait time allows students to produce lengthier and more complex responses. Similarly, Black and Wiliam (1998) also proposed that the use of wait time is an essential component in effective questioning.

Two types of wait time were examined in this study and they were coded respectively as wait time after T-Is (teacher initiation) and wait time after S-Rs (student response). The visual demonstration of when they occur during a typical IRF cycle is given in Figures 8 and 9 in Section 3.5.3.4 above. Wait time after T-Is refers to the wait time teacher gave students after the end of their question and before the onset of students' answers, for the purpose of giving students sufficient time to think of an answer. Wait time after S-Rs refers to the wait time after the end of a student's answer before the onset of the teacher's feedback, for the purpose of giving students time to think and decide if they would like to add more to their answers or giving other students time to respond.

3.5.3.6 Teacher monologue

Teacher monologue emerged from the data as a rather common type of teacher talk the teacher-student interaction in this study. It is a period of uni-directional lecturing a teacher provided to the students without asking a question to elicit student speculations, explanation of their understandings and so on. An example is given earlier in Section 5.2.4. The analysis of the time length and frequency of it could provide another perspective in understanding classroom interaction. For example, a higher time length and frequency would indicate a more teacher-dominated interaction pattern and a lower level of interaction with students.

3.5.3.7 Teacher nomination

An important line of literature on teacher nomination come from the work on teacher assessment practice, particularly in questioning. Black and Wiliam (1998) argued that nominating students to answer and having a hands down policy promote better student engagement. In discussing the importance of providing opportunities for students to talk, they mentioned a common problem in classrooms, which is often the same few students answering teacher questions. As these students probably already know the answer, they frequently indicate their wish to speak up. If teachers also often go with these students, an understanding is created in the classroom that the ideas of the rest of the class are not interesting to the teacher and they may feel demotivated to risk making mistakes in front of the class. Thus, the conceptualization of teacher nomination is allowing teachers to find out what individual students know and do not know by selecting a random student who does not have their hands up. This is considered an effective assessment device, termed as 'no hands-up' technique in Black and Wiliam's (1998) work.

In a classroom, teacher's nomination of an individual student to answer a question can take place in the following possible situations, shown in Table 20. In this current study, only the first two situations were explored.

Situations where teacher nominations take place	Applicable to this research

1).Teacher nominates a student right after a question, before students have the time to volunteer their answer or indicate their wish to answer.	Yes
2).Teacher nominates a student after certain period of silence, as no students volunteer their answer or indicate their wish to answer	Yes
3).Teacher nominates a student when one or multiple students indicate their wish to answer.	No

Table 20 typical situations where teacher nominations take place

When teacher nomination takes place in situation 3), it does not really fulfil the function of it argued in the literature, explained above, as the nomination is still directed to the few students who have their hands up. However, based on the video recordings of the 30 lessons, situation 3) above rarely happened in this research. It was mainly situation 1) and 2) in this research, which both essentially mean nominating a random student without hands up to assess what they know or do not know. Thus, the teacher nominations coded and analysed in this research were in line with the definition of teacher nominations discussed in the literature mentioned above.

3.5.3.8 Noun-verb ratio in student output

As mentioned in Chapter 2 Literature Review, noun-verb ratio in student talk has been used as an important indicator for understanding the quality of teacher-student interaction in L2 or foreign language classes to facilitate students' language learning (Macaro, Granham, Woore, 2016; Macaro & Mutton, 2002). As noun-verb ratio is closely related to language learning, the examination of it could provide useful evidence on how well language learning was taking place through interaction in the EMI science classes of this research. If the EMI science lessons are supposed to help students with their English language learning, then students need to produce both nouns and verbs to practice using complete sentences with agents and actions, and develop their verb system, which is a crucial area in the English language. Thus, it could be argued that the more verbs students used, the more content-language integrated the EMI lessons were.

The calculation of noun-verb ratio in student talk started with identifying all the codes that represent student talk, i.e., all IRF codes that started with S. Then, the numbers of nouns and verbs in all student talk were counted manually. The repetitions of the same words, which very

often seem to be caused by hesitations or difficulties with the English language, were only counted once. One example is given in Excerpt 4 below.

Excerpt 4

Turn	Timespan	Content	Speaker
61	7:21.0 - 7:23.3	But the first one, is, is what?	Louis

In this example, the verb '*is*', although uttered twice by the student, was only counted once. As the purpose of showing the noun verb ratio is to demonstrate the types of vocabulary the students used and the linguistic complexity of their output, the repetition of the same words therefore should not be counted as new nouns or verbs used.

Another rule is that if there were both content verbs and auxiliary verbs in the same sentence (e.g. negative statements or questions), only the content verbs were counted and auxiliary verbs (e.g. can, do, is) were not. This rule of count is illustrated by Excerpt 5 below.

Excerpt 5

Turn	Timespan	Content	Speaker
33	5:56.4-6:12.1	Maybe they won't have too many intelligence to think, or to like we, like us.	S

In the utterance above, the nouns counted are '*they, intelligence, we, us*' and the verbs counted are '*have, think*'. The auxiliary verb in the negative form '*won't*' was not counted towards the number of verbs. Therefore, the noun verb ratio in this particular sentence is 2:1. This was because that if there were content verbs in students' output, it already means there was a presence of actions, rather than only the agents represented by nouns. Thus, the use of verbs could be represented by the content verbs. However, if there were only auxiliary verbs without any content verbs, such as '*It does*', then the auxiliary verbs were counted.

Following the rules above, the noun verb ratio of all the student talk during teacher-whole class interaction in each lesson was calculated.

3.5.3.9 The use of extended IRF sequences

While the examination of teacher and student turn-taking behaviour could already provide some insights on how the dialogues between teachers and student were conducted, the analysis of IRF sequences of different lengths can allow further investigation on how extended the dialogues were. As elaborated in Chapter 2 Literature Review, extensive IRFRF chains have been argued to benefit students' learning (Hall, 1997; Mortimer & Scott, 2003; Wells, 1993), the use of extensive and thought-provoking dialogues plays a significant role in enhancing students' learning of science and is recognized as one of the main characteristics of Dialogic Teaching (Mercer & Littleton, 2007).

Based on the IRF coding of the lessons, the number of the cycle each act (i.e., I, R, or F) took place within a multi-cycled IRF sequence was marked. This provided the basis of quantifying the number of single-cycled IRFs in each lesson, the number of multi-cycled IRFs of various lengths in each lesson.

3.5.3.10 The explicit focus on language

As highlighted in Chapter 2 Literature Review, previous literature has highlighted the importance of explicit focus on the language forms in immersion programs and it has been argued that it is necessary for particularly enhancing the accuracy of the students' L2 (Lyster, 2007; Murphy, 2014; Sherer et al., 2009; Swain, 1996). The difficulty EMI science students face in learning the language of science also adds to the need for explicit attention to address the language issue (Crandall, 1987; Probyn, 2006). Thus, teachers' explicit effort of teaching language forms, coded as 'language-focused episodes' (LFEs), was included as one aspect of classroom interaction to explore.

The time length was used as the measurement of the quantity of LFEs rather than the number of occurrences. This is because each LFE varied in the effort and attention the teacher put in and

the level of detail of the target linguistic feature being explored. Thus, the number of occurrences would not be an accurate measurement. It was decided the time length would be a reasonable way of quantifying and representing the effort that was put in to provide explicit language instruction.

3.5.3.11 Teacher questions

As explained in Chapter 2 Literature Review, teachers' use of questions is an important component in teacher-student interaction. The strategic use of it has also been widely discussed in the literature of science education (Graesser & Person, 1994; Kawalkar & Vijapurkar, 2013; Yip, 2001).

To obtain the total number of teacher questions in each lesson was calculated, all turns coded as T-I (number) was identified in NVivo. Turns coded as T-I (A), teacher initiation for actions, were not included. To obtain the number of different types of teacher questions in each lesson, the turns coded for a specific teacher questioning approach (e.g., '*pumping*') or a type (e.g., '*recall*') were identified in NVivo. The unit of analysis here is individual teacher questions.

What was also quantified was the time length of the whole dialogue each question was situated within, to take into consideration the student responses and teacher feedback involved in the exchange. This is explained earlier in Section 3.5.2.7. As all the turns in the dialogues were coded according to the questioning approaches and types, the time length of the dialogues was produced in NVivo. The unit of analysis here is dialogues rather than individual teacher questions.

3.5.3.12 Student questions

Compared to the vast body of literature on teacher questions, there has been significantly fewer studies on student questions (Chin & Brown, 2002). The value of student questions is also elaborated in Chapter 2 Literature Review.

Similar to teacher questions, the quantitative analysis process of student questions was conducted in NVivo through identifying all the codes with S-I, meaning all the student initiations. This produced the number of all student questions in each lesson. The codes for different types of student questions were also identified to quantify the number of each type of questions asked in each lesson.

3.5.4 Qualitative analysis for classroom interaction

Among the 12 parameters of classroom interaction that were quantified, some of them were also analysed qualitatively through examining the lesson transcripts and identifying typical practices to understand how the target behaviours took place. Lesson excerpts which can demonstrate the typical or common practices in relation to a parameter of classroom interaction, i.e., teacher monologues, were selected to be presented in Chapter 4 Results for Classroom Interaction. These excerpts can provide a more in-depth understanding of the content of certain parameters, give meaning to the quantitative results, and show how the quantified parameters actually took place in the classrooms. In the literature, there has been criticism about using only quantitative data analysis to understand classroom interaction and thus neglecting the important information that can only be obtained by qualitative data analysis (Edwards & Westgate, 1994; Mercer, 2010; Tsui, 1995; Wragg, 2012). This criticism is particularly true with systematic observation procedures, which typically analyse classroom data with a set of pre-determined categories (McIntyre & Macleod, 1986). Although the coding framework of classroom interaction in this study include both pre-determined categories (e.g., IRF, certain types of teacher and student questions) and newly developed categories derived from the lesson observation data (e.g., teacher monologue, certain types of teacher and student questions), as explained in Section 3.5.2, qualitative data analysis is still necessary to provide the context and the content of certain quantified behaviour.

For example, two lesson excerpts were provided in Section 4.1.4.1 in Chapter 4 later to demonstrate the turn-taking behaviour in the lessons, which was shown to be teacher-dominated regarding the number of turns and the turn lengths by the quantitative results. The lesson excerpts

showed how the turn-taking behaviour was realized in the classroom, which was typically a result of teachers leaving certain words or phrases for the students to fill in and teachers accepting single word answers from the students for an open-ended question. This example demonstrates how the qualitative data analysis provided enriched and deeper understandings of classroom interaction in this study.

Another example that demonstrates how the qualitative data analysis complemented the quantitative data analysis to understand how the target behaviour took place in the classrooms is the qualitative analysis of the context of the higher-level thinking student questions. A look at the lesson transcripts of the coded higher-level thinking student questions shows that they took place in the same lesson. Thus, the context of this lesson, i.e., a student-led debating activity, was brought to attention and was regarded as important information for understanding higher-order thinking student questions in this study. The details of the analysis can be found in Section 4.1.12.3 in Chapter 4.

The use of coding schemes to understand classroom interaction behaviour was also criticised for treating classroom data as isolated entities (Tsui, 1995). Thus, while conducting qualitative analysis of the quantified classroom interaction behaviour, when possible, connections were also made among different coding categories to understand more holistically the classroom interaction in the lessons, where certain coded behaviour could be a reason or result of others. For example, when reading the lesson transcripts of the student talk, the high noun-verb ratio of student talk, which was one quantified parameter, was found to have possibly been influenced by the teacher questions. The analysis can be found in Section 4.1.8.3. Similarly, while reading the lesson transcripts of *pumping* questions, a type of teacher questions, a pattern of limited student output received was also noticed, despite frequent use of it to supposedly foster student talk. This is highlighted in Section 4.1.11.3 and connections were made with other coded parameters, including student turn length, the noun verb ratio of student talk, teachers' use of repetition and reformulation of questions. The qualitative data analysis of the quantified behaviours also served to make connections among different categories of the coded behaviours and provide a coherent understanding of the classroom interaction in this study.

In summary, the coding of 12 aspects of classroom interaction behaviour and the use qualitative data analysis to complement the quantitative analysis all aimed to achieve a more accurate and comprehensive understanding of the classroom interaction in this study. The use of both quantitative and qualitative data analysis of classroom interaction is also an example of a mixed-method design, as explained in Section 3.1.1 earlier. Considering the highly complex nature of classroom interaction (Tsui, 1995), multiple data analysis methods enabled by a mixed-method design are needed to enhance the validity of the findings.

3.6 Data analysis for Research Question 2 & 3 - teacher and student beliefs questionnaires

This section explains the data analysis methods for the teacher beliefs questionnaires and the student beliefs questionnaires, which address Research Question 2 on teacher beliefs about teaching science and English in EMI science classes, and Research Question 3 on student beliefs on the same issue.

3.6.1 Scoring of teachers' and students' answers in the beliefs questionnaires

In both the teacher beliefs questionnaire and the student beliefs questionnaire, the answers to all multiple-choice questions in the science learning section and the language learning section were given a score, from 1 to 5. In the teacher beliefs questionnaire, these sections are Section 1 and Section 2, and in the students' questionnaire, they are Section 4 and Section 5. In the section on science learning, the higher a score is, the more alignment the view is with the constructivist view. In the section on language learning, the higher a score is, the more favourable the view is for a teacher supporting the learning of English in EMI classes. Some of the items demonstrate a transmissionary view of science learning or an unfavourable view of language learning, and the score of these items was a reverse of the original answer.

Taking Item 2 in the science section for an example, as shown below, a transmissionary view of teaching science is shown, negating the constructivist view. An answer of '5 (strongly agree)'

would be given a score of 1. An answer of '4 (agree)' would be given a score of 2, and '3 (neutral)' would be given a score of 3.

2. When introducing a new topic, asking students about what they already know about the topic is **not** necessary.

Regarding the items that are phrased consistent with the constructivist view or a favourable view of language learning, the scores of them were the same with the original answers. The distributions of the views are shown in Tables 7 and 9 in Section 3.4.2.2.1 earlier. As explained earlier in this chapter, the multiple-choice items in Section 1 and Section 2 of the teacher beliefs questionnaire and Section 4 and Section 5 of the student beliefs questionnaire are matching.

The scoring process was completed in SPSS.

3.6.2 Descriptive statistics of the questionnaire items

After scoring all teachers' and students' answers to the multiple-choice questions in the section on science learning and the section on language learning, the mean and standard deviations of the scores were calculated. The mean and standard deviations for each subscale were also obtained to provide an overview of the teachers' and students' views, which are presented in Chapter 5 Teachers' background and beliefs and Chapter 6 Students' background and beliefs. The descriptive statistics of the teachers' and students' original answers were also calculated.

It needs to be noted that the sample size of the questionnaire 15 is too small for factor analysis. As Field (2009) notes, the sample size that allows a reliable factor analysis test needs to be at least 300. Thus, the establishment of the sub-scales in Section 1 on science teaching and Section 2 on language teaching in the teacher beliefs questionnaire was based on the literature review conducted and the existing questionnaire consulted during the development of the questionnaire,

as explained earlier in Section 3.4.2.2.1. Factor analysis was also deemed unsuitable for the student beliefs questionnaire because of the low number of question items there are in each subscales (Field, 2009).

The teachers' and students' answers to other multiple-choice questions were also analysed through descriptive statistics, including the mean and standard deviation. Regarding the open-ended questions, all teachers' and students' answers were read through and common themes were identified (Mills, Durepos, & Wiebe, 2010).

3.7 Data analysis for Research Questions 2&3 - teacher and student interviews

All the interviews in this study were transcribed verbatim and analysed in NVivo 11. The transcription focused on the content of the interviews and thus features such as stress, pause and so on were not transcribed.

The qualitative analysis of the interviews followed a mixture of inductive and deductive thematic coding process. Thematic coding analysis is defined as 'a method for identifying, analysing and reporting patterns or themes within data' (Braun & Clarke, 2006, p.6). As explained in Braun & Clarke's (2006) work, there are two major ways to generate themes within data - inductive or 'bottom up' way (e.g., Frith & Gleeson, 2004) and deductive or 'top down' way (e.g., Boyatzis, 1998). The deductive way of themantic analysis is also called 'theoretical way' (Boyatzis, 1998), which means the analysis if driven by the researcher's theoretical or analytic interest. This deductive analyst-driven approach directed the first step of the analysis process, i.e., establishing the pre-determined themes, and the inductive data-driven apporach guided the second step of the analysis process, i.e., identifying the common themes that emerged from the data.

The deductive or theoretical coding process first involved the establishment of two overarching themes, guided by Research Questions 2 and 3, i.e., teacher or student beliefs about science teaching and teacher or student beliefs about English teaching in EMI science classes. Then, under each of the two domains, the sub-theme of teacher or student beliefs about the role of interaction in particular was also established, as Research Questions 2 and 3 specified. In addition, the issue of whether the teacher could implement their teaching plan or teach according to their beliefs was also explicitly enquired about, as shown in the post-lesson interview protocol and the general interview protocol. The teachers' answers can also reflect their beliefs, and possibly provide explanations of the classroom interaction observed in this study. Thus, the theme of translating beliefs into practice was also established. Other pre-determined themes are the influence of the parallel CMI programs on the classroom interaction behaviour in EMI science classes, as explicitly addressed in the post-lesson interview protocol, and the influence of grade level, included in the general interview protocol.

Following the established themes, an inductive thematic coding approach was undertaken to identify the common sub-themes under the overarching themes about beliefs about science teaching and English language teaching, and translation of beliefs into practice. For example, in the teacher interviews, under the overarching theme of teacher beliefs about teaching English in EMI science classes, apart from the pre-established sub-theme of the role of interaction, three other sub-themes emerged as common areas that were frequently mentioned by the teachers - explicit teaching of vocabulary, use of assessment and teachers' identification of their role as a language teacher. This process of the coding of the teacher interviews and the student interviews was iterative, which is a main principle of qualitative data analysis (Dörnyei, 2007). This means that the codes were refined and modified along the process of the coding of the interviews to make sure all the themes were systematically covered. These themes are presented in Chapter 5 and Chapter 6.

10% of the interview data (i.e.,11 interviews, including 8 teacher interviews and 3 student interviews) were also coded again by me to ensure the reliability of the coding process. This was conducted more than six months after the interview data were first coded. Due to the limited resources of this PhD project, only intra-rater coding was conducted, although inter-rater coding would have been helpful. The Cohen's Kappa coefficient for intra-rater coding is 0.82, showing a reasonably high level of coding reliability (Robson, 2002; Landis and Koch, 1977).

As the language of the interviews were in English with the foreign monolingual teachers and in Mandarin with the students, the transcription was conducted through the language of the interviews. When quotations from student interviews were presented in Chapter 6, they were English translations of the original comments. To ensure the accuracy of the translation, back translation was also conducted. A bilingual who is highly proficient in Mandarin and English translated the quotations from the student interviews that are presented in Chapter 6 back into Mandarin. The translation was then compared with the original quotations in Mandarin to check if the meaning changed from what the students originally said. This ensured the translation into English was accurate.

After the data analysis of the teacher interviews and student interviews was completed, the findings from interviews and questionnaire were compared and this way findings about teacher and student beliefs can be validated through different sources. This process is demonstrated in Chapters 5 and 6. In addition, the findings from the interviews and questionnaires were also consulted to find explanations of the classroom interaction pattern observed, which is shown in Chapter 7. Thus, the different sources of data triangulate each other and help to enhance the validity of this study. The limitations that arose from the research methodology are explained in Chapter 7 Discussion and Conclusion.

3.8 Ethics

This study was approved by the CUREC (see Appendix 8).

Based on what are available through personal connections, the information about the schools with the possibility of access were researched through their own school websites to decide if they were in the target school population. Representation of certain variations, explained in the sampling frame in Section 3.2.2 earlier, were also sought after.

Prior to the data collection, the soft version of the information letters and consent forms were sent to the Principal of the school or the Director of the foreign high school program to ensure they had enough information and time to make the decision as to whether they were willing to participate.

On the first day of my visit, the hard copy of the research information letters (see Appendix 9) and consent forms (see Appendix 9) were also shown to the Principal or Director of the program, and the foreign science teachers. I also explained the purpose of my study in person to the Principal or the Director of the foreign programs, and the science teachers at the school. This also allowed school leaders and teachers to ask questions. It was emphasized that all the information collected, including the video recordings and audio recordings, and questionnaires, will be kept strictly confidential. It was made clear that the lesson observations were not to evaluate the teachers or students. The information letters and the consent forms were given to the teachers for them to sign. In some cases, most of the science teachers at the school visited agreed to participate and in other cases some science teachers opted out.

I was also allowed to explain the research to the students with the information letter in Chinese (see Appendix 9) in class. It was also made clear to the students the purpose of the research, protection of their identities, the use of their data and so on. Students were also welcomed to ask questions.

Regarding teachers' and students' questionnaires, it was explained to both the teachers and students that filling in the questionnaires was voluntary. Similarly, I also explained participation in interviews was voluntary. It was emphasized there would be no penalty if they refuse to participate.

All schools, teachers and students are anonymized in the thesis and any future publications. To protect the participants' identity, extra caution was also exercised in this thesis to not give the name of the city where the schools are located to ensure the protection of their privacy.

Chapter 4 Results for Classroom Interaction

This chapter describes the classroom interaction in the 30 lessons observed through presenting quantitative and qualitative data of 12 parameters. The research question being addressed in this chapter is as follows:

Research Question 1: What are the features of the classroom interaction in EMI science classes between foreign monolingual science teachers and Chinese students in foreign high school programs in China?

4.1 Results of the 12 parameters

For each parameter, the average result of the 30 lessons will be presented first, followed by the variation across the 30 lessons. This is to first provide the overall pattern and then show the differences among individual lessons, which can shed light on how well the average result represents the situation in all the 30 lessons. For the parameters where qualitative result is also provided, it is either embedded within the average result section, or presented independently as a separate section.

4.1.1 The breakdown of lessons

4.1.1.1) Average

Figure 10 below demonstrates the average time length distribution of different activities across the 30 lessons.

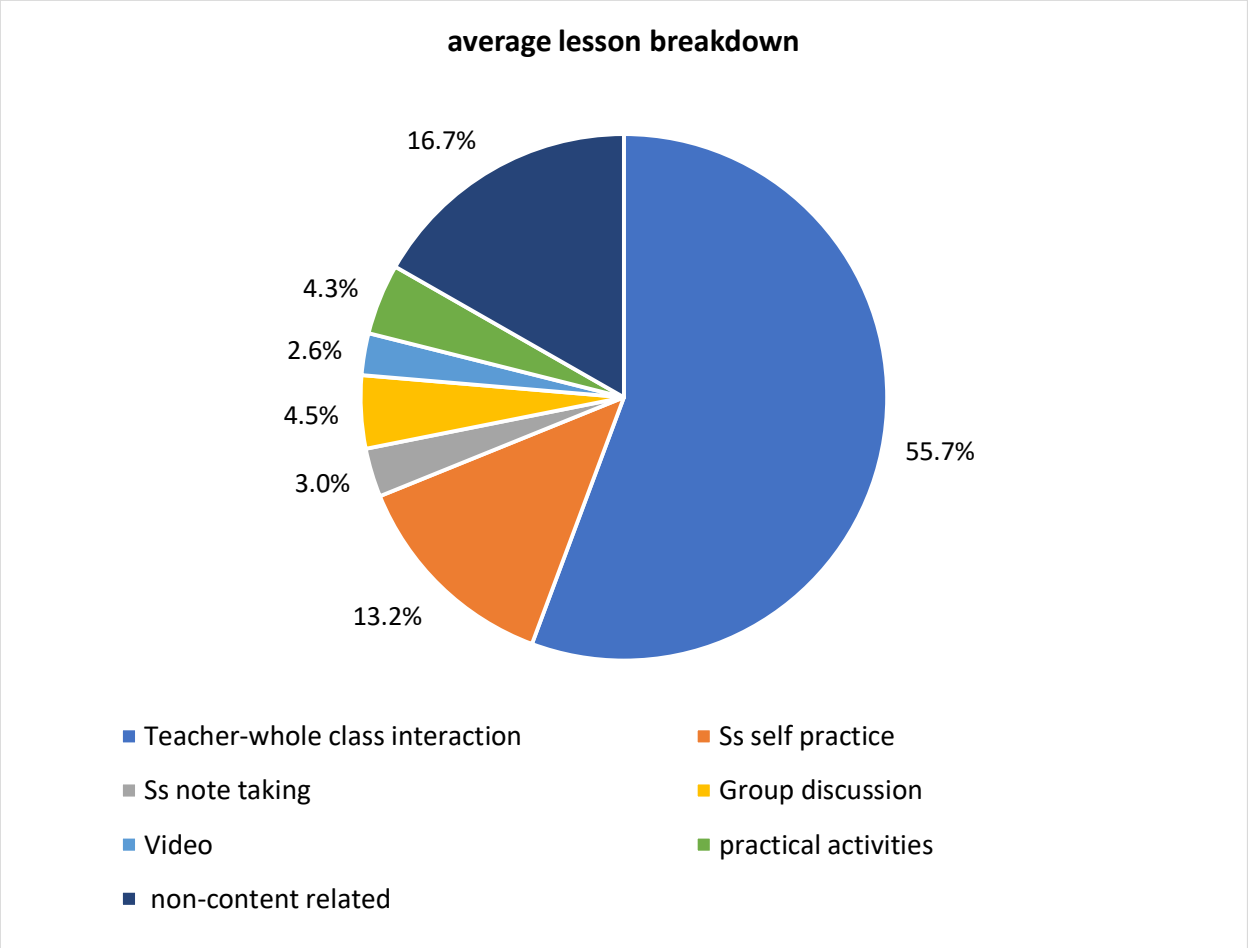


Figure 10 average lesson breakdown

First of all, the non-content related time on average took up a sizable proportion (i.e., 16.7%) the lesson time. This could be explained by the often observed late start of the lessons when the teachers were waiting for students to arrive, and the lengthy time spent on taking register, classroom management, or chatting between the teachers and students about non-academic matters. Although non-content related time is not the focus of this research, this still shows that the teachers on average tended to spend a rather considerable amount of lesson time on the non-academic matters. Description of non-content talk can be found in Section 3.5.2 of Chapter 3 Methodology.

Regarding the lesson time directly related to the actual academic content, the pie chart above shows that teacher-whole class interaction on average took up 55.7% of the overall lesson time. The second lengthiest content-related activity was students' self-practice (13.2%). Student talk (6.9%), group discussion (4.5%) and practical activities (4.3%), which are widely considered

possessing significant pedagogical value in the constructivist view of teaching science (Howe & Abedin, 2013; Jenkins, 2000; Kang & Wallace, 2005), all took up a relatively small amount of the lesson time (i.e., less than 10%).

4.1.1.2) Variation

Table 21 below shows the results of instructional activities in each lesson.

Time percentage of instructional activities to the whole lesson											
no.	Name	T talk	Ss talk	wait time (overall)	Ss self practice	Ss note taking	Group discussion	Video	Lab work/hands-on	non-content related	total
1	Edward 1st lesson	68.4%	8.4%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	22.7%	100.0%
2	Edward 2nd lesson	2.9%	0.0%	0.0%	0.0%	0.0%	73.2%	0.0%	0.0%	24.0%	100.0%
3	Christina 1st lesson	55.5%	5.8%	1.7%	15%	1%	17%	0.0%	0.0%	3.9%	100.0%
4	Christina 2nd lesson	29.4%	5.1%	1.3%	21.2%	0.0%	36.7%	0.0%	0.0%	6.3%	100.0%
5	Chad 1st lesson	53.6%	4.7%	0.0%	41.2%	0.0%	0.0%	0.0%	0.0%	0.4%	100.0%
6	Chad 2nd lesson	41.8%	1.1%	1.1%	40.0%	0.0%	0.0%	12.3%	0.0%	3.7%	100.0%
7	Colin 1st lesson	67.4%	4.4%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	27.9%	100.0%
8	Colin 2nd lesson	47.0%	0.3%	0.1%	0.9%	0.0%	0.0%	0.0%	33.3%	18.5%	100.0%
9	Emma 1st lesson	42.7%	2.8%	0.5%	12.5%	19.5%	0.0%	0.0%	0.0%	22.0%	100.0%
10	Emma 2nd lesson	39.2%	3.3%	0.4%	0.0%	35.1%	0.0%	0.0%	0.0%	22.0%	100.0%
11	George 1st lesson	45.0%	17.2%	5.2%	0.0%	0.0%	0.0%	15.5%	0.0%	17.1%	100.0%
12	George 2nd lesson	56.3%	12.8%	7.1%	0.0%	0.0%	0.0%	0.0%	0.0%	23.9%	100.0%
13	Hannah 1st lesson	53.2%	5.5%	3.1%	15.9%	0.0%	0.9%	0.0%	19.9%	1.5%	100.0%
14	Hannah 2nd lesson	22.4%	2.0%	1.6%	45.1%	0.0%	2.0%	0.0%	0.0%	26.9%	100.0%
15	Jenny 1st lesson	49.1%	4.2%	1.5%	32.6%	0.0%	0.0%	0.0%	0.0%	12.6%	100.0%
16	Jenny 2nd lesson	20.7%	1.5%	0.7%	0.0%	0.0%	0.0%	0.0%	77.1%	0.0%	100.0%
17	Johnson 1st lesson	83.8%	2.5%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	12.7%	100.0%
18	Johnson 2nd lesson	92.5%	1.4%	0.3%	0.4%	1.7%	0.0%	0.0%	0.0%	3.8%	100.0%
19	Kate 1st lesson	12.5%	1.6%	0.8%	53.3%	0.0%	0.0%	0.0%	0.0%	31.8%	100.0%
20	Kate 2nd lesson	41.0%	19.9%	3.7%	0.0%	0.0%	0.0%	0.0%	0.0%	35.3%	100.0%
21	Mat 1st lesson	55.1%	1.6%	0.4%	0.0%	0.0%	0.0%	28.3%	0.0%	14.6%	100.0%

22	Mat 2nd lesson	71.0%	1.3%	0.1%	0.0%	0.0%	0.0%	1.9%	0.0%	25.7%	100.0%
23	Lennon 1st lesson	49.0%	17.1%	2.1%	26.7%	0.0%	0.0%	0.0%	0.0%	5.2%	100.0%
24	Lennon 2nd lesson	44.9%	17.6%	2.9%	29.0%	0.0%	0.0%	0.0%	0.0%	5.6%	100.0%
25	Louis 1st lesson	56.7%	2.2%	0.4%	18.4%	0.0%	0.0%	0.0%	0.0%	22.3%	100.0%
26	Louis 2nd lesson	57.2%	1.8%	0.3%	28.1%	0.0%	0.0%	0.0%	0.0%	12.6%	100.0%
27	Nicolas 1st lesson	29.4%	35.1%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	35.3%	100.0%
28	Nicolas 2nd lesson	37.9%	7.0%	4.8%	0.0%	4.9%	0.0%	19.2%	0.0%	26.3%	100.0%
29	Stella 1st lesson	49.0%	9.1%	0.1%	0.0%	17.9%	4.6%	0.0%	0.0%	19.3%	100.0%
30	Stella 2nd lesson	43.6%	9.2%	3.6%	15.6%	9.7%	0.0%	0.0%	0.0%	18.3%	100.0%
	Average	**47.3%**	**6.9%**	**1.5%**	**13.2%**	**3.0%**	**4.5%**	**2.6%**	**4.3%**	**16.7%**	
	SD	**19.2%**	**7.8%**	**1.8%**	**16.6%**	**7.8%**	**14.9%**	**6.9%**	**15.4%**	**10.6%**	

Table 21 breakdown of each lesson

As Table 21 above shows, several categories had a rather large standard deviation (SD). For example, group discussion had a SD of 14.9%, which is considerably larger than the average, 4.5%. This indicates that there was considerable variation among the 30 lessons regarding the time lengths of different teaching activities and the lesson designs also varied. However, what was rather consistent across the 30 lessons was the large percentage of teacher talk, with relatively small variation. This feature will be elaborated in detail later in Section 4.1.3.

4.1.2 Teacher-whole class interaction time

4.1.2.1) Average

Figure 11 below demonstrates the average time percentage of teacher-whole class interaction to the whole lesson time in the 30 lessons.

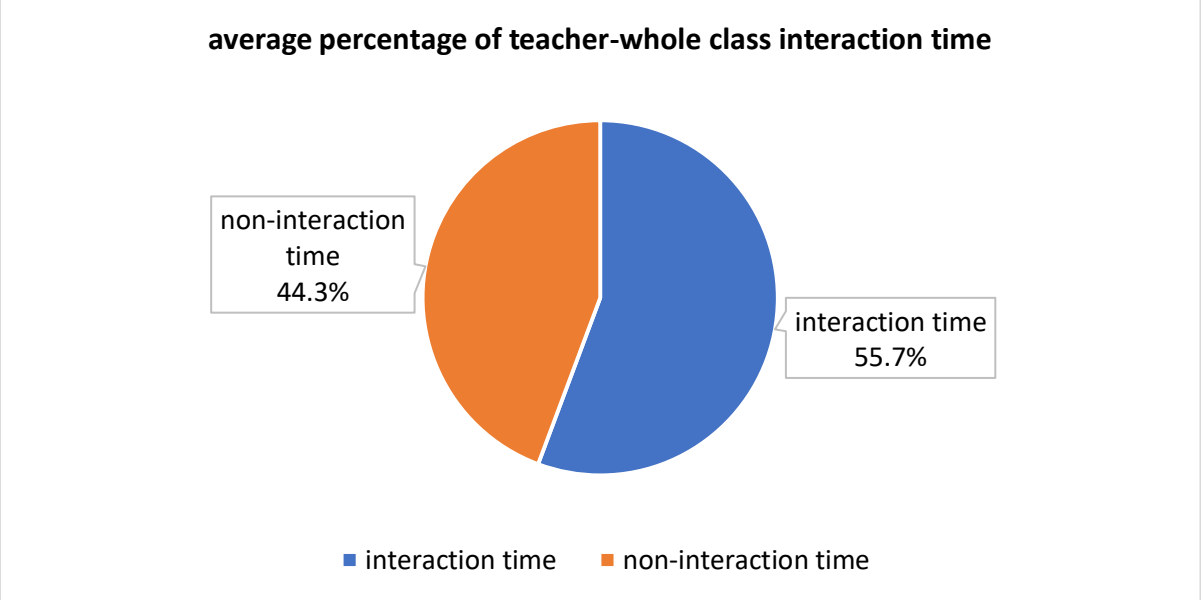


Figure 11 average time percentage of teacher-whole class interaction

On average the teacher-whole class interaction time occupied approximately half (i.e., 55.7%) of a lesson. This demonstrates that on average the teacher-whole class interaction occupied a small majority of the lesson time, with the rest of the lesson time, as Section 4.1.1 above shows, spent on students' self-practice, note taking, group discussion and so on.

4.1.2.2) Variation

Table 22 below lists the time length and percentage of teacher-whole class interaction time in each lesson is below.

no.	lesson	interaction time (in mins)	percentage of interaction time to whole lesson
1	Edward 1st lesson	30.9	77.3%
2	Edward 2nd lesson	1.3	2.9%
3	Christina 1st lesson	28.4	63.0%
4	Christina 2nd lesson	16.1	35.8%
5	Chad 1st lesson	35.0	58.3%
6	Chad 2nd lesson	26.4	44.0%
7	Colin 1st lesson	43.3	72.1%
8	Colin 2nd lesson	28.4	47.4%
9	Emma 1st lesson	27.6	46.0%
10	Emma 2nd lesson	25.7	42.9%
11	George 1st lesson	30.3	67.4%
12	George 2nd lesson	34.3	76.2%
13	Hannah 1st lesson	27.8	61.8%
14	Hannah 2nd lesson	11.7	26.0%
15	Jenny 1st lesson	24.7	54.8%
16	Jenny 2nd lesson	10.3	22.9%
17	Johnson 1st lesson	39.3	87.3%
18	Johnson 2nd lesson	42.4	94.2%
19	Kate 1st lesson	8.9	14.9%
20	Kate 2nd lesson	38.8	64.6%
21	Mat 1st lesson	25.7	57.1%
22	Mat 2nd lesson	32.6	72.4%
23	Lennon 1st lesson	40.9	68.2%
24	Lennon 2nd lesson	39.2	65.4%
25	Louis 1st lesson	35.6	59.3%
26	Louis 2nd lesson	35.6	59.3%
27	Nicolas 1st lesson	25.9	64.8%
28	Nicolas 2nd lesson	19.9	49.7%
29	Stella 1st lesson	34.9	58.2%
30	Stella 2nd lesson	33.8	56.4%
	Average	**28.5**	**55.7%**
	SD	**10.5**	**28.8%**

Table 22 time percentage of teacher-whole class interaction of each lesson

With a standard deviation of 28.8%, there were a few outliers among the 30 lessons, with some lessons having 80-90% of the lesson time being teacher-whole class interaction and some only having 10%-20%. As the breakdown of the lessons earlier shows, this could be due to the different designs of each lesson and the use of different teaching activities. For example, Aaron's second lesson, with only 2.9% of the lesson time being teacher-whole class interaction, was largely made up by students' group discussion. Jenny's second lesson, with 22.9% of the lesson time being teacher-whole class interaction, was a lab lesson which took place in a lab classroom rather than an ordinary classroom. Hannah's second lesson and Kate's first lesson had a high proportion of students' self-practice, i.e., 45.1% and 53.3%, and thus had low proportions of teacher-whole class interaction, i.e., 14.9% and 22.9%. However, apart from the few outliers, most of the 30 lessons had a percentage of teacher-whole class interaction between 40% and 70% and the average percentage, 55.7%, could to a reasonable degree reflect a common trend among the 30 lessons. This also shows that in the examination of the results on the parameters in the following sections, which are within the teacher-whole class interaction time, it needs to be born in mind that these interactional behaviours only occurred within a proportion of the lesson time and on average a sizable percentage of the lesson time was beyond the teacher-whole class interaction.

4.1.3 Time length and proportion of teacher and student talk

As explained in Chapter 3 Methodology, teacher-whole interaction time includes teacher talk, student talk and wait time. In this section, the first two components are examined. The use of wait time will be explored separately in Section 4.1.5.

4.1.3.1) Average

In this study on average there were 24.1 minutes of teacher talk and 3.4 minutes of student talk in a lesson, occupying 85.6% and 11.6% of the teacher-whole class interaction time of a lesson. This is visualized in Figure 12 below. This means that on average teacher talk took up the vast majority of the interaction time while student output was rather limited.

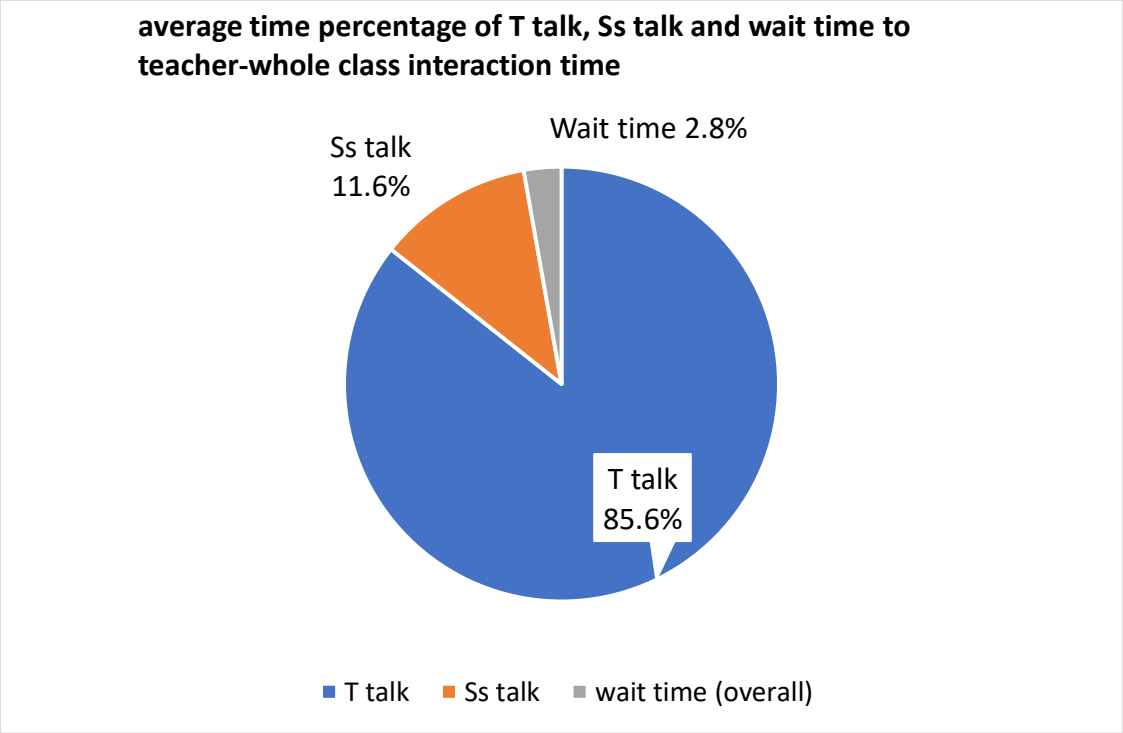


Figure 12 average time percentage of teacher talk, student talk and wait time to teacher-whole class interaction time

It needs to be noted that the percentages were against the teacher-whole class interaction time of a lesson, rather than the whole lesson time. This was because, as Section 4.1.1 and 4.1.2 earlier show, the design of a lesson and the use of different teaching activities varied considerably across the lessons (e.g. having lengthy group discussions or students' self-practice), and this in turn influenced the percentage of teacher talk or student talk to the whole lesson. By examining the percentages to the teacher-whole class interaction time, it allowed the focus to be merely on the time of teacher-whole class talk without the interference of the different lesson designs and use of different teaching activities.

4.1.3.2) Variation

The results of each lesson are shown in Table 23 below.

		length (in mins)			percentage to the teacher-whole class interaction time		
No.	**Name**	**T talk**	**Ss talk**	**wait time (overall)**	**T talk**	**Ss talk**	**wait time (overall)**

1	Edward 1st lesson	27.4	3.4	0.2	88.5%	10.8%	0.7%
2	Edward 2nd lesson	1.3	0	0	100.0%	0.0%	0.0%
3	Christina 1st lesson	25	2.6	0.8	88.1%	9.2%	2.7%
4	Christina 2nd lesson	13.2	2.3	0.6	82.0%	14.3%	3.7%
5	Chad 1st lesson	26.8	2.4	0	91.9%	8.1%	0.0%
6	Chad 2nd lesson	25.1	0.7	0.6	95.0%	2.6%	2.4%
7	Colin 1st lesson	40.4	2.2	0.2	93.5%	6.1%	0.4%
8	Colin 2nd lesson	28.2	0.2	0.1	99.1%	0.7%	0.2%
9	Emma 1st lesson	25.6	1.7	0.3	93.5%	6.1%	0.4%
10	Emma 2nd lesson	23.5	2	0.2	91.4%	7.7%	0.9%
11	George 1st lesson	20.2	7.7	2.4	66.8%	25.5%	7.7%
12	George 2nd lesson	25.3	5.7	3.2	73.9%	16.8%	9.3%
13	Hannah 1st lesson	26.9	2.5	1.4	87.4%	8.1%	4.5%
14	Hannah 2nd lesson	10.1	0.9	0.7	86.3%	7.7%	6.0%
15	Jenny 1st lesson	22.1	1.9	0.7	89.6%	7.7%	2.7%
16	Jenny 2nd lesson	9.3	0.7	0.3	90.3%	6.6%	3.1%
17	Johnson 1st lesson	37.7	1.1	0.4	96.0%	2.9%	1.1%
18	Johnson 2nd lesson	41.6	0.6	0.1	98.2%	1.5%	0.3%
19	Kate 1st lesson	7.5	1	0.5	84.0%	10.6%	5.4%
20	Kate 2nd lesson	24.6	12	2.2	63.4%	30.8%	5.8%
21	Mat 1st lesson	24.8	0.7	0.2	96.5%	2.7%	0.8%
22	Mat 2nd lesson	32	0.6	0	98.1%	1.8%	0.1%
23	Lennon 1st lesson	29.4	10.2	1.3	71.9%	25.0%	3.1%
24	Lennon 2nd lesson	26.9	10.6	1.8	68.6%	26.9%	4.5%
25	Louis 1st lesson	34	1.3	0.3	95.6%	3.7%	0.7%
26	Louis 2nd lesson	34.3	1.1	0.2	96.5%	3.0%	0.5%
27	Nicolas 1st lesson	11.8	14	0.1	45.4%	54.1%	0.5%
28	Nicolas 2nd lesson	15.2	2.8	1.9	76.3%	14.0%	9.7%
29	Stella 1st lesson	29.4	5.4	0.1	84.2%	15.6%	0.2%
30	Stella 2nd lesson	24.2	5.1	2	77.3%	16.3%	6.4%
	Average	**24.1**	**3.4**	**0.8**	**85.6%**	**11.6%**	**2.8%**
	SD	**9.7**	**3.8**	**0.9**	**12.8%**	**11.5%**	**2.9%**

Table 23 time percentage of teacher talk, student talk and wait time of each lesson

As Table 23 above shows, across the 30 lessons the amount of teacher talk was consistently between almost 100% and 60% of the total teacher-whole class interaction time, and student talk was mostly below 20%. A small number of lessons had an obviously higher percentage of student talk, including George's first lesson (25.5%), Kate's second lesson (30.8%), Lennon's

first (25.0%) and second lesson (26.9%), and Nicolas's first lesson (54.3%). The particularly high percentage in Nicolas's first lesson, 54.3%, is mostly due to the class debate activity in that lesson between boys and girls on whether stem cell research should be allowed. Similarly, Kate's second lesson had a sizable proportion of the lesson dedicated to a student group presentation and this use of student ouput intensive activity significantly contributed a higher percentage of student talk in her lesson. However, apart from these outliers, the pattern emerged in most of the lessons was a consistently low time proportion of student talk.

4.1.4 Turn taking behavior between teachers and students

Based on the definition of turns given in Chapter 3 Methodology, results are presented here regarding the numbers of turns teachers and students took during the teacher-whole class interaction time, and the average time length of their turns.

4.1.4.1) Average

Figures 13 and 14 below demonstrate the average number of turns from the teacher and the students in a lesson, and the average time length of a teacher turn and a student turn.

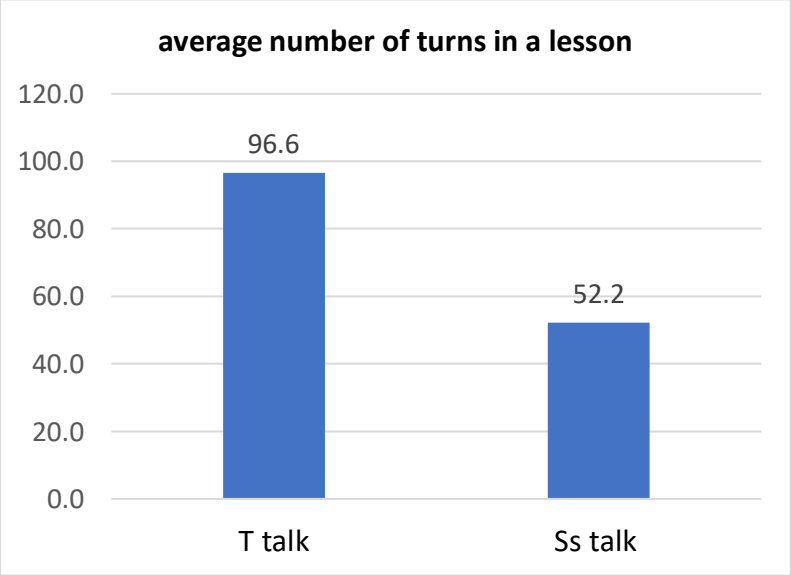


Figure 13 average number of teacher turns and student turns in a lesson

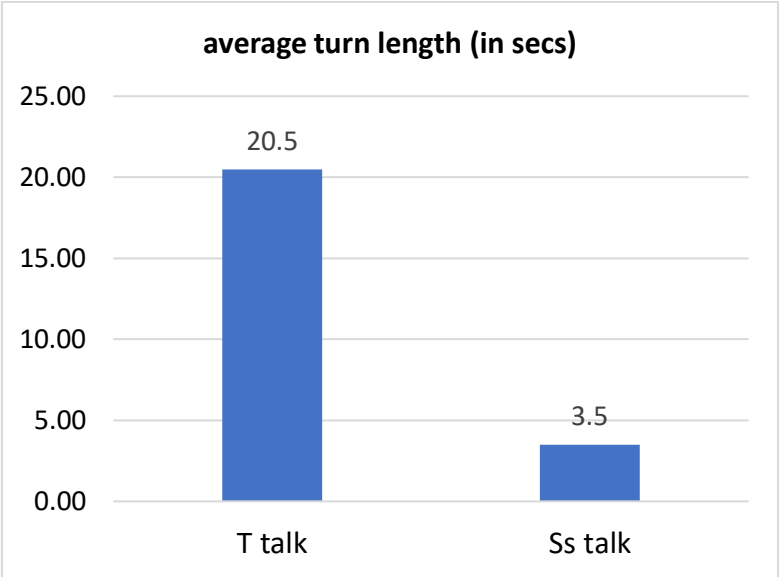
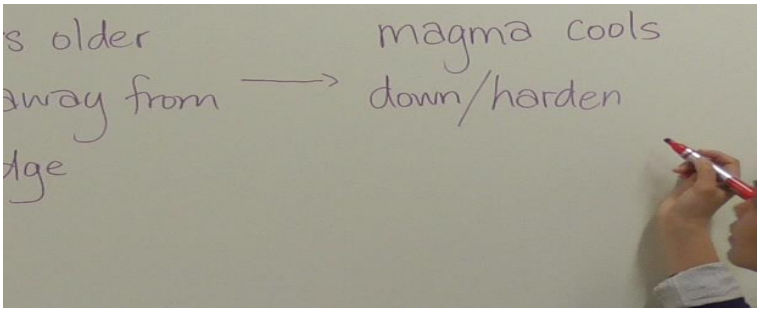


Figure 14 average turn lengths for teacher turns and students turns

As can be seen, on average the teacher took 96.6 turns in a lesson and each turn the teacher spoke for about 20.5 seconds. The students on average took 52.2 turns in a lesson and on average each time they spoke for about 3.5 seconds. The ratio of teacher and student turns is roughly 2:1. This matches with the long-established IRF (inititation-response-feedback) pattern of classroom discourse (Sinclair & Coulthard, 1975), where the teacher asks question, followed by the student's answers and then the teacher provides feedback, as mentioned in Chapter 2 Literature Review. The considerably short average student turn length, 3.5 seconds, means the students in general were not able to sustain a longer turn in this study. The results about turn-taking here also indicate a clear dominance of the teachers. Excerpt 6 below is a typical example of the turn-taking behavior, taken from Christina's second Biology lesson on sea floor spreading.

Excerpt 6

Turn	Timespan	Content	Speaker
28	3:00.0-3:12.0	Now *[T drawing arrow]*, while the uh rocks are being pushed away from the ridge, what's going to happen next? The magma is going to---	T
29	3:12.0-3:13.0	To cool.	Ss

30	3:13.0-3:24.0	* Yeah*, so magma um cools down, hardens and becomes what? *[T writing "magma cools down/ harden"]* 	T
31	3:24.0-3:26.0	Rocks.	S2
32	3:27.0-3:42.0	It becomes, before it becomes into a, which contains lots and lots of iron? Ah, ah Lucy?	T
33	3:42.0-3:45.0	Magnetic.	S3
34	3:46.0-3:54.0	Yes, it will become, the state will become magnetic which is what? It's called--uh Patrick?	T
35	3:54.0-3:56.0	Molten basalt.	S4
36	3:56.0-4:10.0	Exactly. It will become um molten basalt *[T writing "molten basalt"]*, ok?	T

In the example above, the student turns were rather short between one to three seconds and featured single words or phrases, which are key target science concepts in this lesson, such as *magnetic* and *molten basalt*. This was also a result of the way the teacher asked her questions, which left certain key words and phrases for the students to fill out. The teacher turn lengths were much longer. The turn-taking behavior in this excerpt also follows the pattern of teacher asking a question, the student replying and the teacher providing feedback and then asking another question.

Another example is provided below to demosntrate another common behavior of turn-taking in this study where the teacher asked an open-ended question which required a full explanation, but the teacher accpeted the student's answer with only a key word without requiring the students to produce a full sentence to explain the whole idea.

Excerpt 7

Turn	timespan	content	Speaker
11	02:46.0-02:47.0	What would be a Bronsted base then using the same logic?	T
12	02:48.0-02:49.0	Accepts.	S3
13	02:49.0-02:51.0	Yes, anything that accepts a proton, okay?	T

In Excerpt 7 above, the student's turn was only one second, consisting of one word '*accepts*', rather than a complete sentence to describe the whole idea, e.g., '*a Bronsted base would be anything that accepts a proton'*, which would have been a lengthier turn with a more complicated linguistic structure. The teacher then provided the full explanation himself, based on his interpretation of the meaning of the student's answer, and did not require the student to provide a complete sentence. The fact that the student was able to provide the key word, '*accepts*', suggests he probably knew the science concept of Bronsted base, or perhaps vaguely remembered the concept of Bronsted base is related to accepting something. This example demonstrates the common situation in this study where teacher questions received very short answers and the teachers did not push the students to provide a more linguistically complete answer to fully explain their ideas. These situations can also explain the counter-intuitive results where a low time proportion of student talk and a low average student turn length still persisted despite a reasonably high frequency of teacher questions, which will be illustrated in Section 4.1.11 Teachers' questioning approaches later.

More details about the content of student turns are presented later in Section 4.1.8 The ratio of noun and verb in student talk.

4.1.4.2) Variation

The results in each lesson are presented in Table 24 below, with the number of teacher turns and student turns being shown first and then the average turn length of teacher turns and student turns in each lesson.

		number of turns	
No.	**lessons**	**T talk**	**Ss talk**
1	Edward 1st lesson	110	75
2	Edward 2nd lesson	1	0
3	Christina 1st lesson	95	37
4	Christina 2nd lesson	70	32
5	Chad 1st lesson	95	59
6	Chad 2nd lesson	54	16
7	Colin 1st lesson	67	43
8	Colin 2nd lesson	53	10
9	Emma 1st lesson	71	30
10	Emma 2nd lesson	53	14
11	George 1st lesson	231	161
12	George 2nd lesson	209	140
13	Hannah 1st lesson	123	56
14	Hannah 2nd lesson	54	19
15	Jenny 1st lesson	125	52
16	Jenny 2nd lesson	50	27
17	Johnson 1st lesson	62	18
18	Johnson 2nd lesson	59	19
19	Kate 1st lesson	40	15
20	Kate 2nd lesson	129	59
21	Mat 1st lesson	45	17
22	Mat 2nd lesson	46	20
23	Lennon 1st lesson	216	147
24	Lennon 2nd lesson	282	207
25	Louis 1st lesson	83	21
26	Louis 2nd lesson	74	23
27	Nicolas 1st lesson	82	74
28	Nicolas 2nd lesson	135	75
29	Stella 1st lesson	93	51
30	Stella 2nd lesson	92	48
	Average	**96.6**	**52.2**
	Standard Deviation	**62.3**	**49.0**

Table 24 the number of teacher turns and student turns of each lesson

As Table 24 above demonstrates, across the 30 lessons the variation of the number of teacher turns was generally consistent with the variation of the number of student turns. This is unsurprising as the turn taking behavior usually takes the form of the teacher asking questions and students answering. An exception is Nicolas' first lesson, where a debate activity took place and resulted in the number of teacher turns and student turns being almost the same. In this lesson, the students were arguing back and forth with each other and thus more numbers of student turns were produced.

As shown in Table 24 above, the number of teacher turns in most lessons was consistently between 50 and 150, and the number of student turns were mostly below 50. A few lessons had a significantly higher number of both teacher and student turns, such as 231 teacher turns and 161 student turns in George's first lesson, 209 teacher turns and 140 student turns in George's second lesson, 216 teacher turns and 147 student turns Lennon's first lesson and 282 teacher turns and 207 student turns in Lennon's second lesson. This means that in these particular lessons there were considerably more frequent turn exchanges between the teacher and students. This largely stemmed from more frequent use of questions from the teachers in these lessons. As the results in Section 4.1.11 Teachers' questioning approaches later show, there were 169 and 147 teacher questions in George's first and second lessons, and 157 and 211 questions in Lennon's two lessons while the average number of teacher questions in a lesson was only 54.1. These higher numbers of teacher questions initiated more turn-exchanging opportunities where student and teachers followed up with each other's utterances. However, the pattern that emerged in most of the lessons features a rather low number of student turns and a much higher number of teacher turns.

Following the results about the number of turns, the average turn length of teacher turns and student turns in each lesson is shown in Table 25 below.

		average turn length (in secs)	
No.	**lessons**	**T talk**	**Ss talk**
1	Edward 1st lesson	14.9	2.7
2	Edward 2nd lesson	78.0	0
3	Christina 1st lesson	15.4	4.2
4	Christina 2nd lesson	11.3	3
5	Chad 1st lesson	16.9	2.4
6	Chad 2nd lesson	27.9	2.6
7	Colin 1st lesson	30.0	3
8	Colin 2nd lesson	31.9	1.2
9	Emma 1st lesson	21.6	1.7
10	Emma 2nd lesson	23.6	5.5
11	George 1st lesson	5.3	2.9
12	George 2nd lesson	7.3	2.5
13	Hannah 1st lesson	13.1	2.9
14	Hannah 2nd lesson	11.2	2.8
15	Jenny 1st lesson	10.6	2.2
16	Jenny 2nd lesson	11.2	1.5
17	Johnson 1st lesson	36.5	3.8
18	Johnson 2nd lesson	42.3	2
19	Kate 1st lesson	11.3	3.8
20	Kate 2nd lesson	11.4	12.2
21	Mat 1st lesson	33.1	2.5
22	Mat 2nd lesson	41.7	1.8
23	Lennon 1st lesson	8.2	4.2
24	Lennon 2nd lesson	5.7	3.1
25	Louis 1st lesson	28.9	1
26	Louis 2nd lesson	15.3	2.9
27	Nicolas 1st lesson	8.7	10.4
28	Nicolas 2nd lesson	6.7	2.2
29	Stella 1st lesson	19.0	6.4
30	Stella 2nd lesson	15.8	6.3
	Average	**20.5**	**3.5**
	Standard Deviation	**15.1**	**2.5**

Table 25 average turn length of teacher turns and student turns in each lesson

As Table 25 above shows, the average turn length for teacher turns varied considerably across the 30 lessons while the average turn length for student turns was consistently at a very low level. This indicates that in some lessons the teacher spoke significantly longer per turn than the teacher in other lessons. For example, Johnson and Mat spoke for about 50 seconds on average per turn in both of their lessons, which is well about the average of 20.49 seconds. The

particularly long average turn length of 78 seconds in Aaron's second lesson was due to the one long teacher monologue given at the beginning of the lesson where lengthy instruction was given on how the students were required to do group discussions.

In comparison, the average turn length of student turns ranged narrowly between 0 to 10 seconds, and was mostly below 5 seconds in the 30 lessons. The exceptions were Kate's second and Nicolas's first lesson, where Kate's second lesson consisted of a student group presentation activity and Nicolas's first lesson had a class debate, as also explained in the sections earlier.

With some outliers in the sample, however, the overall trend in the 30 lessons is that the teacher talk made up the absolute majority of the overall teacher-whole class interaction time, and the teacher turns considerably outnumbered the student turns, and the student turns were rather short in most of the lessons.

4.1.5 Wait time (WT)

The results of the two types of wait time, wait time after teacher initiations (WT after T-Is) and the wait time after student responses (WT after S-Rs), are presented below. The definition of them is given in Section 3.5.2.3 The coding of wait time.

4.1.5.1) WT after T-Is: Average

On average wait time after T-Is occurred 9.9 times per lesson while teacher-initiations on average took place 54.1 times. This means 18% of the T-Is were followed by wait time. This shows the teachers in this study did not use wait time frequently after they asked a question. Here, the number of T-Is did not include the teacher initiations for actions, coded as T-I (number) A, as explained in Section 3.5.2.1 The coding of IRFs. This was because the teacher initiations for actions were not meant for nominating any student to give a verbal response. The

total length of wait time used after T-Is in a lesson on average was 45.3 seconds. The average minimum and maximum of wait time after T-Is in a lesson were 1.7 seconds and 11.2 seconds.

The minimum and maximum wait time used in each lesson were considered in this lesson rather than the average length of wait time in a lesson because the purpose of the wait time after T-Is is to give processing time to individual students and the length of wait time is often largely dependent on the situations of the individual students, the cognitive demand of the question, and so on. For example, the teacher may give shorter wait time to a student who is advanced and longer wait time to a student who is slower. A teacher may also give shorter wait time to avoid embarrassing a student who seems to struggle to come up with an answer. Thus, the various factors influencing the use of wait time make it difficult to interpret the meaning of the average length of wait time in a lesson. Instead, the minimum and maximum time length can show the range of the length of wait time after T-Is, which indicates the teacher's techniques to vary the use of wait time to accommodate different situations. Thus, the wide range from the average minimum (1.7 secs) to the average maximum (11.1 secs) indicates a high level of differentiation with regards to the use of wait time by the teachers in this study to possibly accommodate individual students' needs.

4.1.5.2) WT after T-Is: Variation

Table 26 below lists the results for each lesson.

	wait time after T-I (teacher initiations)					
no.	**lesson**	**number of occurrences (after T-I)**	**Number of T-Is**	**Total length in each lesson (secs)**	**minimum (secs)**	**maximum (secs)**
1	Edward 1st lesson	2	65	13.0	5.0	8.0
2	Edward 2nd lesson	0	0	0.0	0.0	0.0
3	Christina 1st lesson	20	48	47.0	1.0	4.2
4	Christina 2nd lesson	10	39	35.7	1.6	7.2
5	Chad 1st lesson	7	66	38.0	1.0	24.0
6	Chad 2nd lesson	14	29	38.5	0.1	8.1
7	Colin 1st lesson	3	43	10.0	3.0	4.0

8	Colin 2nd lesson	1	14	3.0	3.0	3.0
9	Emma 1st lesson	7	39	7.9	2.0	4.0
10	Emma 2nd lesson	3	21	5.1	1.3	2.8
11	George 1st lesson	30	169	141.3	0.6	23.2
12	George 2nd lesson	27	147	190.4	0.6	31.3
13	Hannah 1st lesson	17	56	79.5	1.0	15.0
14	Hannah 2nd lesson	8	31	31.7	1.8	8.1
15	Jenny 1st lesson	19	66	34.6	0.1	4.0
16	Jenny 2nd lesson	2	27	19.3	0.9	17.4
17	Johnson 1st lesson	8	22	26.0	1.1	19.9
18	Johnson 2nd lesson	0	30	0.0	3.0	7.0
19	Kate 1st lesson	4	26	29.0	5.0	9.0
20	Kate 2nd lesson	15	54	131.9	2.0	37.0
21	Mat 1st lesson	6	12	12.0	2.0	2.0
22	Mat 2nd lesson	1	18	2.0	2.0	2.0
23	Lennon 1st lesson	8	157	75.6	2.2	34.3
24	Lennon 2nd lesson	22	211	88.1	0.9	8.6
25	Louis 1st lesson	3	30	12.0	2.0	5.0
26	Louis 2nd lesson	5	29	9.9	1.1	3.0
27	Nicolas 1st lesson	3	37	6.4	1.6	3.4
28	Nicolas 2nd lesson	25	69	109.2	1.2	13.3
29	Stella 1st lesson	10	36	42.8	1.7	11.2
30	Stella 2nd lesson	18	33	119.6	1.7	17.8
	average	**9.9**	**54.1**	**45.3**	**1.7**	**11.2**
	standard deviation	**8.9**	**50.4**	**49.5**	**1.2**	**9.8**

Table 26 the use of wait time after teacher initiations in each lesson

As several aspects of wait time were explored, e.g., the number of occurrences, total length and the range (i.e., the minimum and the maximum), it is difficult to look into the variations in all these aspects. The total length of wait time in each lesson was selected to examine the variation across the lessons, as the representation of the teacher's use of wait time after T-Is. Although it does not fully represent all the aspects, the total length is influenced by the number of occurrences, the minimum and maximum length of wait time used in the lesson. Hence, it was considered as a reasonable aspect to reflect the variations of the use of wait time across the 30 lessons.

With a standard deviation of 49.5 seconds for an average of 45.3 seconds of wait time after T-Is in total in a lesson, there were considerable variations across the 30 lessons. However, this large

standard deviation was partly due to several outliers, such as George's both lessons, Nicolas's second lesson, Kate's second lesson, and Stella's second lesson, where the total wait time after T-Is was more than 100 seconds in these lessons. This means in these lessons, wait time was used considerably more than the rest of the lessons. However, while the five lessons were outliers, the majority of the lessons had a total length of wait time after T-Is as little as below 60 seconds per lesson, which is the overall pattern that emerged from the lessons.

4.1.5.3) WT after S-Rs: Average

The second type of wait time examined in this study is wait time after students' responses (S-Rs). Again, an explanation of wait time after S-Rs is given in Section 3.5.2.3 The coding of wait time. On average wait time after S-R took place only 0.5 times per lesson out of 51.3 student responses in a lesson. On average the total length was 2.1 seconds per lesson, with the average minimum length being 1.1 seconds and average maximum length being 1.3 seconds. This indicates the clear scarcity of wait time after S-Rs, which means that the teachers in this study rarely waited after their students gave answers to see if the student wanted to add more to their own answers or other students wanted to respond to that answer. However, it needs to be noted that there were occasional cases where the teacher explicitly asked if any other students had anything to add, which also had a similar function as wait time after S-Rs, but were not counted in the calculation of wait time after S-Rs.

4.1.5.4) WT after S-Rs: Variation

Table 27 below shows the results for each lesson.

no.	lesson	number of occurrences (after S-R)	number of S-Rs	total length of wait time after S-R in each lesson	minimum (secs)	maximum (secs)
1	Edward 1st lesson	0	67	0	N/A	N/A
2	Edward 2nd lesson	0	0	0	N/A	N/A
3	Christina 1st lesson	0	32	0	N/A	N/A
4	Christina 2nd lesson	0	37	0	N/A	N/A
5	Chad 1st lesson	0	59	0	N/A	N/A

6	Chad 2nd lesson	0	13	0	N/A	N/A
7	Colin 1st lesson	0	42	0	N/A	N/A
8	Colin 2nd lesson	0	10	0	N/A	N/A
9	Emma 1st lesson	0	30	0	N/A	N/A
10	Emma 2nd lesson	2	14	5.8	2.8	3.0
11	George 1st lesson	0	161	0	N/A	N/A
12	George 2nd lesson	0	140	0	N/A	N/A
13	Hannah 1st lesson	1	56	4	4.0	4.0
14	Hannah 2nd lesson	1	19	10.6	6.6	6.6
15	Jenny 1st lesson	1	52	5.9	6.0	6.0
16	Jenny 2nd lesson	0	27	0	N/A	N/A
17	Johnson 1st lesson	0	18	0	N/A	N/A
18	Johnson 2nd lesson	1	19	7	7.00	7.00
19	Kate 1st lesson	0	15	0	N/A	N/A
20	Kate 2nd lesson	1	59	3	3.0	3.0
21	Mat 1st lesson	0	11	0	N/A	N/A
22	Mat 2ndlesson	0	20	0	N/A	N/A
23	Lennon 1st lesson	0	150	0	N/A	N/A
24	Lennon 2nd lesson	5	206	17.8	1.1	6.0
25	Louis 1st lesson	1	11	4	4.0	4.0
26	Louis 2nd lesson	0	21	0	N/A	N/A
27	Nicolas 1st lesson	1	75	1	N/A	N/A
28	Nicolas 2nd lesson	1	75	4.9	N/A	N/A
29	Stella 1st lesson	0	51	0	N/A	N/A
30	Stella 2nd lesson	0	49	0	N/A	N/A
	average	**0.5**	**51.3**	**2.1**	**1.1**	**1.3**
	standard deviation	**1**	**50.4**	**4.1**	**2.1**	**1.6**

Table 27 the use of wait time after student responses in each lesson

In shown in Table 27 above, there was no wait time after S-Rs in many lessons and only a small group of lessons had a larger amount of it, including Hannah's second lesson (10.6 seconds in total), Lennon's second lesson (17.8 seconds in total). Thus, although with several exceptional cases, most lessons had a minimal use of wait time after S-Rs and the teachers did not leave much space to see if any students had further answers or comments, as the average results also indicate.

4.1.6 Teacher monologues

Among the teacher turns, some of them were teacher monologues. As mentioned in Chapter 3 Methodology, teacher monologues were also coded in all lessons as they emerged from the data as a common practice. To reiterate, teacher monologues were the parts of a teacher's talk to the whole class where no questions were asked to the students and no student output was invited. During teacher monologues, the teacher was lecturing the students in a unidirectional manner. An explanation can also be found in Section 3.5.2.4.

4.1.6.1) Average

Figure 15 below demonstrates the average time proportion of teacher monologues to teacher-whole class interaction time, with reference to the time proportion of the other components as well.

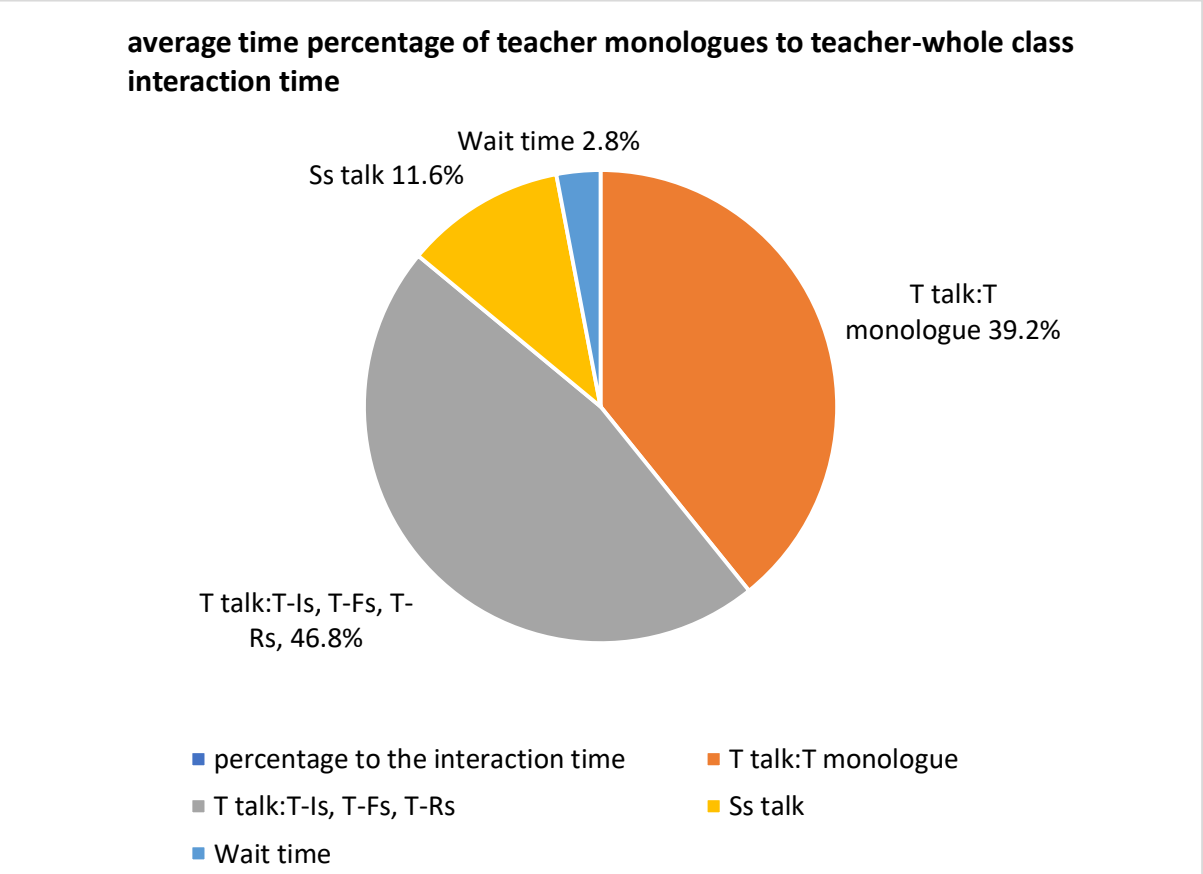


Figure 15 average time percentage of teacher monologues

On average teacher monologues occupied 39.2% of the total teacher-whole class interaction time in a lesson, where no student output was invited. Again, the reason for showing the percentage to the teacher-whole class interaction time rather than the total lesson time was to eliminate the impact of the widely different use of instructional activities across the 30 lessons.

The other measurements of teacher monologues include that they on average took place 13.1 times in one lesson and there were 10.3 minutes of them in a lesson. The average time length of one teacher monologue was 49.6 seconds, which was not particularly long. However, the teachers used monologues quite frequently, i.e., 13.1 times in a lesson, thus resulting a considerable overall usage of it.

The results of teacher monologues indicate an overall rather high level of teacher dominance in the interaction time and limited space for student output. This is also in congruence with teacher talk occupying 85.6% and student talk occupying 11.6% of the interaction time on average, shown earlier in Section 4.1.3 Time length and proportion of teacher and student talk. The results of teacher monologues further demonstrate that 45.6% of the teacher talk (i.e., 39.2%/86%) was actually teacher monologues, and the teacher talk directly involved in conversations with students, e.g., teacher questions and feedback, was only 54.4% of the total teacher talk.

4.1.6.2) Variation

The use of teacher monologues in each lesson is shown in Table 28 below.

No.	Name	number of occurrences	Total length of T monologues (mins)	average length of one T monologue (secs)	percentage to teacher-whole class interaction time
1	Edward 1st lesson	5	4.4	52.6	14.2%
2	Edward 2nd lesson	1	1.3	78.0	100.0%
3	Christina 1st lesson	18	13.9	46.3	49.8%
4	Christina 2nd lesson	2	2.4	72.0	14.9%
5	Chad 1st lesson	9	12.4	82.5	41.5%

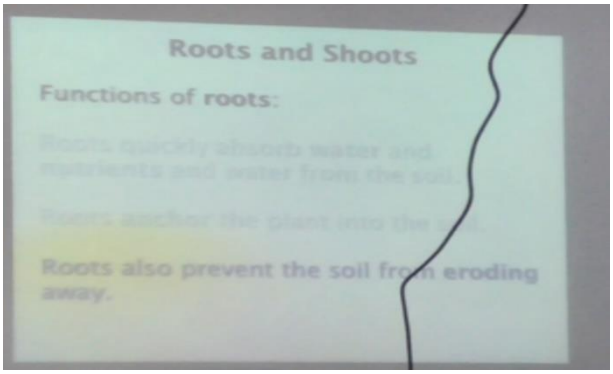
6	Chad 2nd lesson	11	17.9	97.7	67.9%
7	Colin 1st lesson	27	20.5	45.5	57.2%
8	Colin 2nd lesson	36	28.2	47.0	99.1%
9	Emma 1st lesson	3	5.3	105.3	19.8%
10	Emma 2nd lesson	19	12.7	40.0	69.7%
11	George 1st lesson	8	3.4	25.6	11.2%
12	George 2nd lesson	12	5.2	25.9	15.1%
13	Hannah 1st lesson	11	5.4	29.3	17.5%
14	Hannah 2nd lesson	3	3.0	59.5	25.4%
15	Jenny 1st lesson	18	10.7	35.8	43.5%
16	Jenny 2nd lesson	7	1.8	15.4	17.5%
17	Johnson 1st lesson	22	22.5	61.3	57.2%
18	Johnson 2nd lesson	16	22.5	84.5	53.2%
19	Kate 1st lesson	2	0.8	25.0	9.3%
20	Kate 2nd lesson	7	2.6	21.9	6.6%
21	Mat 1st lesson	28	19.6	42.0	76.3%
22	Mat 2nd lesson	12	21.8	109.1	67.0%
23	Lennon 1st lesson	10	4.0	23.9	9.7%
24	Lennon 2nd lesson	2	1.6	46.6	4.0%
25	Louis 1st lesson	20	22.6	67.7	63.4%
26	Louis 2nd lesson	22	12.4	33.7	61.3%
27	Nicolas 1st lesson	6	2.0	20.3	7.7%
28	Nicolas 2nd lesson	20	5.2	15.5	26.1%
29	Stella 1st lesson	16	12.8	48.1	36.8%
30	Stella 2nd lesson	20	10.2	30.7	32.7%
	average	**13.1**	**10.3**	**49.6**	**39.2%**
	standard deviation	**8.9**	**8.2**	**26.9**	**27.9%**

Table 28 the use of teacher monologues in each lesson

As Table 28 above shows, there were certain variations regarding the use of teacher monologues across the 30 lessons. With an average percentage being 39.2%, the percentages in individual lessons ranged from 6.6% to 100%. However, about half of the lessons had more than 40% of the teacher-whole class interaction time being teacher monologues. The lessons that had remarkably low time proportion of teacher monologues also had instructional activities that are more student output intensive, such as Kate's second lesson where students were asked to give presentations, and Nicolas's second lessons where a class debate was held. Despite these variations, the overall trend features a rather heavy presence of teacher monologues in teacher-whole class interaction.

Regarding the average length of a teacher monologue, most of the lessons had a consistent average length of below 49.6 seconds. However, several teachers typically used lengthier monologues, such as Chris, Johnson and Mat. To provide a comprehensive presentation of the teacher monologues in the lessons of this study, an example of a shorter teacher monologue and an example of a longer one is given below. The first excerpt, Excerpt 8, comes from Stella's second Biology lesson on the structure of plants, demonstrating the use of a short teacher monologue. In this excerpt, the teacher was showing students PPT slides with information about the functions of roots.

Excerpt 8

Turn	Timespan	Content	Speaker
72	12:30.4 - 12:37.6	Today we will start looking at the function of roots. This is the first one you can write down.	T
73	12:37.5 - 13:02.3	[students taking notes from PPT]  (The words on the PPTs are: Functions of roots: Roots quickly absorb water and nutrients and water from the soil. Roots anchor the plant into the soil. Roots also prevent the soil from eroding away.)	
74	13:02.3 - 13:30.4	So, the first function of roots, not the first in order, but just the first one we are talking about. Roots can quickly absorb water and nutrients from the soil because they are underground. They are in the soil. They have mechanisms to absorb water, to absorb nutrients to bring into the roots and into the plants.	T
75	13:30.4 - 13:52.6	[students taking notes from PPT]	
76	13:52.6 – 14:00.7	Second function, roots anchor the plant into the soil, what does anchor mean again?	T

In Turn 74, the teacher gave a monologue of about 28 seconds without asking students questions where she was explaining one of the functions of roots and the students were asked to copy down the information on the PPT slides. In this lesson, short teacher monologues were frequently used to explain the content shown on PPT slides and the students were asked to write down the information on the slides. This is an example of a relatively short teacher monologue.

Excerpt 9 below comes from Mat's second Biology lesson on genetic modification and is an example of a long teacher monologue.

Excerpt 9

Turn	Timespan	Content	Speaker
16	5:27.0-10:57.0	Anyway, right so… [pause for 3 seconds] First rule of genetics, you know we're talking about genetics? No. Eh… First rule of genetics… every single species known to man, and I say that because eh… I don't know about the or, or, organisms on some planets from far far away… But anyway, the organisms that we have on earth so far, that we have determined, **all share the exact same genetic code**, okay? Every species we've looked at, whether it's a bacteria, or a fungi, or a plant, or a bird, or a human, or a mouse, doesn't matter what it is, the uni…the genetic code is exactly the same. It's an A, a T, a C and a G. And, we have the enough. When the *[inaudible],* make the protein to these… to these DNA proteins. The enzymes or the proteins will be exactly the same. **Exactly the same.** If I take a gene, an insulin, from humans, and I put it in a horse, it looks like a human insulin. I put it in a bacteria, it's human insulin. I put it in a plant, human insulin. It's universal. This is why we say the genetic code is universal. It doesn't matter which organism is put in, the organism reads it exactly the same, which is very cool, in fact I would say, very cool. So, why are we able to do genetic modification? Why are we able to use transgenics? Why are we able to take genes from one species and put it into another? The answer is, because, *the genetic code is universal*.	T

		[*The teacher then explained in detail the steps of undertaking genetic transfer.*]	

In Turn 16 of Excerpt 9 above, the teacher gave a lengthy monologue of 5 minutes and 30 seconds to explain the reason why genetic transfer can work, i.e., the genetic code is universal, and the steps of undertaking genetic transfer. During this lengthy monologue, the teacher did not ask students questions to elicit speculations or checking their previous knowledge or letting students discuss in groups. This class of students, as the teacher mentioned in a pre-lesson interview, was of high academic attainment and high English proficiency level. This might have played a role in the teacher's decision of using such a lengthy monologue to explain highly complicated content knowledge without checking the students' understandings.

4.1.7 Teacher nominations (T-Ns)

Teacher nominations is another parameter to understand teacher-student interaction. The use of teacher nominations in all the 30 lessons was examined through counting the number of occurrences and the percentage they took in the number of teacher initiations (T-Is) in each lesson. The purpose was to show how often teachers used nominations when they asked questions. An example of the use of teacher nominations is given in Section 3.5.2.5 The coding of teacher nomination.

It needs to be noted that in the calculation of the percentage of T nominations to T-Is, the number of T-Is did not include the teacher initiations for actions, coded as T-I (number) A. This was because these initiations were not meant for nominating any student to give a verbal response. The lesson observations also show that the students had English names, which were what the teachers used in their nominations.

4.1.7.1) Average

On average there were 5.6 teacher nominations used in one lesson and they occupied 10.8% of all the teacher initiations (except the teacher initiations for actions), which is a rather low proportion, as demonstrated in Figure 16 below. This reveals that it was not common practice for teachers to nominate students to answer his/her questions. Instead, they most often let students voluntarily provide their answers.

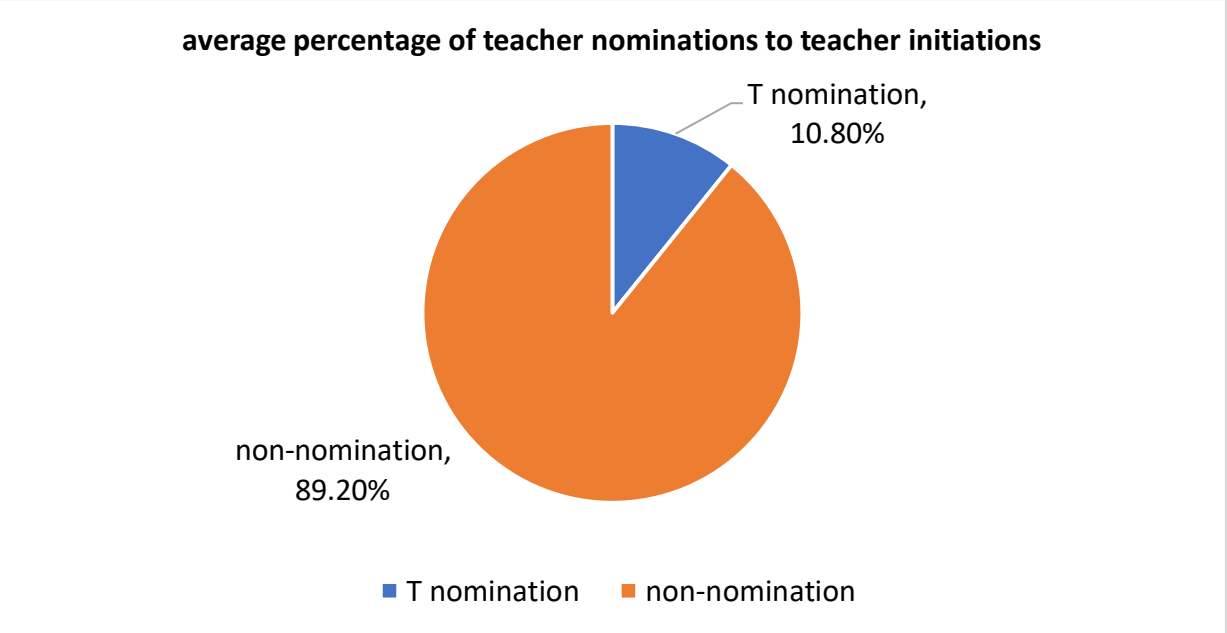


Figure 16 average frequency percentage of teacher nominations to teacher initiations

It needs to be noted that although the use of teacher nominations means specific students were asked to answer a question, a look at the lesson transcripts shows that sometimes there were actually no responses from the students nominated. An example is shown in Excerpt 10 below, taken from George's first Biology lesson on types of sugar. He is also one of the outliers who used considerably more teacher nominations. In this excerpt, the teacher nominated several students to give another word for complex sugar.

Excerpt 10

Turn	timespan	content	Speaker	Teacher nomination
35	2:15.0 - 2:22.6	What's another? what's another word? Close your book. What's another word? Sophie, do you know?	T	T-N

36	2:22.6 - 2:25.8	[wait time]		
37	2:25.8 - 2:27.8	Vincent, do you know?	T	T-N
38	2:27.7 - 2:30.9	[wait time]		
39	2:30.9 - 2:31.8	Robin, do you know?	T	T-N
40	2:31.8 - 2:32.8	Carbohydrate.	Robin	
41	2:32.8 - 2:45.8	Carbohydrate, no, yes, but a complex sugar, a complex sugar, we already said polysaccharide, many sugars.	T	
42	2:45.8- 2:49.6	Em, there's another word for complex sugar. Starts with an S?	T	
43	2:49.6 - 2:50.6	Starch	Robin	
44	2:50.6 - 2:55.6	Starch, ok, all right!	T	

As can be seen in Excerpt 10 above, the teacher used three nominations in Turns 35, 37 and 39, asking three individual students to answer the question asking for another word for complex sugar. However, the first two students were not able to provide an answer while the teacher waited for about three seconds after the nomination for both of them. The third student, Robin, first provided an incorrect answer, carbohydrate, and then gave the correct answer, starch, after the teacher gave a clue of the word starting with an S. It can be seen in this example that the frequent use of teacher nominations took place in the situation where no response was given by students, which was often observed in the lessons with a higher number of teacher nominations. In addition, the teacher initiations in Turns 37 and 39 were coded with an R, showing these initiations were repetitions or reformulations of a previous question. This is a common coping strategy used by many teachers while there were no student responses. This will be discussed in Section 4.1.9 The use of IRF sequences.

4.1.7.2) Variation

Table 29 below shows the use of teacher nominations in each lesson.

no.	lessons	no. of T-Ns	no. of T-Is	percentage of T-Ns in T-Is
1	Edward 1st lesson	12	65	18.5%
2	Edward 2nd lesson	0	0	0.0%
3	Christina 1st lesson	6	48	12.5%
4	Christina 2nd lesson	14	39	35.9%
5	Chad 1st lesson	4	66	6.1%
6	Chad 2nd lesson	4	29	13.8%
7	Colin 1st lesson	7	43	16.3%
8	Colin 2nd lesson	0	14	0.0%
9	Emma 1st lesson	1	39	2.6%
10	Emma 2nd lesson	1	21	4.8%
11	George 1st lesson	32	169	18.9%
12	George 2nd lesson	38	147	25.9%
13	Hannah 1st lesson	5	56	8.9%
14	Hannah 2nd lesson	0	31	0.0%
15	Jenny 1st lesson	0	66	0.0%
16	Jenny 2nd lesson	1	27	3.7%
17	Johnson 1st lesson	2	22	9.1%
18	Johnson 2nd lesson	0	30	0.0%
19	Kate 1st lesson	0	26	0.0%
20	Kate 2nd lesson	0	54	0.0%
21	Mat 1st lesson	5	12	41.7%
22	Mat 2nd lesson	3	18	16.7%
23	Lennon 1st lesson	0	157	0.0%
24	Lennon 2nd lesson	0	211	0.0%
25	Louis 1st lesson	0	30	0.0%
26	Louis 2nd lesson	0	29	0.0%
27	Nicolas 1st lesson	0	37	0.0%
28	Nicolas 2nd lesson	5	69	7.2%
29	Stella 1st lesson	14	36	38.9%
30	Stella 2nd lesson	14	33	42.4%
	average	**5.6**	**54.1**	**10.8%**
	standard deviation	**9.2**	**50.4**	**13.6%**

Table 29 the use of teacher nominations in each lesson

A look at the use of T-Ns in all the lessons shows most lessons had a minimal presence of T-Ns (e.g., 0% to 15%) while in a small group of lessons T-Ns were much more frequently used,

including Christina's second lesson (35.9%), George's second lesson (25.9%), Mat's first lesson (41.7%), and Stella's both lessons (38.9% and 42.4%). A look at the lesson transcripts shows that the more frequent use of T-Ns in these five lessons was partly due to the often no responses from the students, which led to the teacher nominating other students, as illustrated in Excerpt 10 above. However, despite these several exceptional cases, the use of T-Ns was limited in most of the 30 lessons. Most teachers asked questions without nominations, leaving the questions being answered by volunteers, or sometimes unanswered. This means that the benefits of teacher nominations, as discussed in Section 3.5.3.7, were not fully taken advantage of in the lessons of this research.

4.1.8 The ratio of noun and verb in student talk

Previous sections in this chapter have provided results regarding the quantity of student talk, such as the time proportion of student talk and turn length of student talk. This section will provide insights on the linguistic structure of student talk through examining the noun and verb ratio in student talk. The method of the calculation is explained in Section 3.5.3.8 Noun-verb ratio in student output.

4.1.8.1) Average

The average ratio of nouns and verbs in student talk in the 30 lessons was 4.9:1, meaning with almost every five nouns there was one verb in student talk. This shows an overall strong noun-orientated nature of the student output and relatively scant production of verbs. As also confirmed by the examination of the transcripts of the 30 lessons, in many cases the student output was not in the form of complete sentences or clauses and often featured a single noun or noun phrase. An example is provided in Excerpt 11 below, taken from Hannah's first Biology lesson about the reproductive structure and the life cycle of plants.

Excerpt 11

Turn	Timespan	Content	Speaker
75	16:21.0 -	What is pollen? [pause 5 seconds] What is the pollen grain? Why is it	T

	16:30.0	important in the life cycle?	
76	16:30.0 - 16:31.0	Sperm.	S5
77	16:31.0 - 16:33.0	Sperm. It contains sperm, okay? That's one of the other important reproductive adaptations. [T pointing to the slide]	T

In Turn 76, the students used only one noun '*sperm*' to explain why pollen is important in the life cycle of a plant, rather than producing a complete sentence to explain the whole idea that pollen is important because it contains sperm. To respond to the student's answer of one key word, in Turn 77, the teacher accepted this single-noun answer and extended it into a sentence with the use of the verb '*contain*' to describe the full idea – '*It contains sperm'*, based on her interpretation of the meaning of the student's answer. This is a typical example of students' use of only a noun or a noun phrase in their answers without composing a complete sentence with verbs to fully explain their ideas.

As demonstrated in Excerpt 11 above, the teachers in the lessons rarely asked the students to repeat their answers using a verb or a complete sentence. Instead, the teachers usually provided the complete answer with verbs themselves. Thus, there was a lack of requirement from the teachers to push the students to try to integrate the use of verbs to describe their ideas fully.

4.1.8.2) Variation

Table 30 below shows the noun verb ratio of student talk in each lesson.

No.	Name	no. of noun in Ss talk	no. of verb in Ss talk	noun verb ratio in Ss talk
1	Edward 1st lesson	84	14	6:1
2	Edward 2nd lesson	0	0	0:0
3	Christina 1st lesson	53	21	2.5:1
4	Christina 2nd lesson	17	11	1.5:1
5	Chad 1st lesson	52	9	5.8:1
6	Chad 2nd lesson	7	4	1.8:1
7	Colin 1st lesson	17	3	5.7:1
8	Colin 2nd lesson	5	4	1.3:1
9	Emma 1st lesson	30	4	7.5:1

10	Emma 2nd lesson	12	0	12:0
11	George 1st lesson	195	14	14:1
12	George 2nd lesson	142	16	8.9:1
13	Hannah 1st lesson	74	20	3.7:1
14	Hannah 2nd lesson	32	8	4:1
15	Jenny 1st lesson	42	7	6:1
16	Jenny 2nd lesson	22	2	11:1
17	Johnson 1st lesson	20	5	4:1
18	Johnson 2nd lesson	19	3	6.3:1
19	Kate 1st lesson	26	9	2.9:1
20	Kate 2nd lesson	99	41	2.4:1
21	Mat 1st lesson	13	5	2.6:1
22	Mat 2nd lesson	13	3	4.3:1
23	Lennon 1st lesson	209	21	10:1
24	Lennon 2nd lesson	106	13	8.2:1
25	Louis 1st lesson	21	6	3.5:1
26	Louis 2nd lesson	20	6	3.3:1
27	Nicolas 1st lesson	528	289	1.8:1
28	Nicolas 2nd lesson	37	16	2.3:1
29	Stella 1st lesson	148	72	2.1:1
30	Stella 2nd lesson	163	91	1.8:1
	average	**73.5**	**23.4**	**4.9:1**
	standard deviation	**104.25**	**54.1**	**3.6**

Table 30 the noun verb ratio of student talk in each lesson

As shown in Table 30 above, while the ratio is high in all lessons, a small number of lessons also had a considerably higher ratio, indicating a particularly strong noun-oriented structure in students' utterances. These outliers include George's first lesson, Emma's second lesson, Jenny's second lesson, Lennon's first lesson. It also needs to be noted that the ratio only reflects the comparison between the number of nouns and verbs and does not reflect the absolute number of them. The absolute number of verbs produced in student talk during teacher-whole class interaction in each lesson is mostly below 20. The strong noun-oriented nature in student talk in this lesson is also considered as having been impacted by the teacher questions, which will be illustrated below in Section 4.1.8.3) The role of teacher questions in the high noun-verb ratio in student talk.

There were also several exceptions where the student talk had a lower noun-verb ratio. Among the exceptions were Nicolas's first lesson, largely occupied by a class debate activity, and Kate's second lesson, consisting of student presentations. In addition, among the lessons without a particular student-output intensive activity, Stella's two lessons also had a lower noun-verb ratio (i.e., 2.1:1 and 1.8:1) and a higher number of verbs in student talk (i.e., 72 and 91). This could particular be due to the students' high English proficiency level, as commented by the teacher. Mat's two lessons also had a low noun-verb ratio (i.e., 2.6:1. 4.3:1) but this could be due to the limited output overall from the students as both the number of nouns and verbs in the two lessons are very low (i.e., 13 nouns and 5 verbs in the first lesson and 13 nouns and 3 verbs in the second lesson).

Despite certain variations across the 30 lessons, the overall trend is that the students used considerably fewer verbs than nouns to communicate with their teachers, and overall the student talk was noun-oriented. Thus, they might not have been sufficiently developing their verb system in English and might not have sufficiently experimented with expressing science ideas in their L2 as science often involves processes (e.g., motion, energy transfers), which requires heavy use of verbs.

4.1.8.3) The role of teacher questions in the high noun-verb ratio in student talk

The results above show the noun-oriented nature of the student output in the 30 lessons. This indicates the students' scant production of verbs and possibly a lack of English proficiency in composing full sentences, as shown in Excerpt 11 above. However, a look at the lesson transcripts shows that teacher questions may also have contributed to the one-noun answers that many students provided. It also needs to be born in mind that the teacher questions were also motivated by the lesson objectives.

George's first Biology lesson, which has the highest noun verb ratio, 14:1, shows that the significant high ratio might be due to the nature of many of the questions he asked, as his questions were mainly focusing on reinforcing and clarifying the specific terms for different types of sugar. Two examples from George's first lesson are shown below in Excerpts 12 and 13.

Excerpt 12

Turn	Timespan	Content	Speaker
60	9:00.0 - 9:09.6	So, what would be a complex sugar? What would we call a complex sugar?	T
61	9:09.6 - 9:10.5	Polysaccharide.	Ss
62	9:10.5 - 9:19.1	Yeah, because they are made of like, hundreds of glucose molecules.	T

Excerpt 13

Turn	Timespan	Content	Speaker
67	9:47.8 - 10:00.6	Ok, ok, em, I'm not gonna speak much more about carbohydrates. Ok, what, what is another micro molecule besides carbohydrate?	T
70	10:00.6 - 10:03.8	[wait time]	
72	10:03.8 - 10:08.0	Another micro molecule. Nathan, do you know?	T
74	10:08.0 - 10:10.2	Fat.	Nathan
76	10:10.1 - 10:16.2	Fat. Fat, you know fat? What's another word for fat?	T
77	10:16.2 - 10:16.3	Lipid.	Ss
79	10:18.5 - 10:19.1	Yes.	Ss
80	10:19.1 - 10:31.1	Yeah. [T writing "Lipid" on the board],	T

In Excerpts 12 and 13 above, the teacher's questions were phrased in a way to elicit Biology-specific terms, such as '*what would we call XX?*', '*what is another XX?*', *'what's another word for XX?*'. The purpose seemed to be reviewing and reinforcing the key technical terms, such as *polysaccharide* and *lipid*, which was in fact specified in the pre-lesson interview by the teacher as part of the lesson objectives. As there were many questions like this in this lesson, it is

unsurprising that the number of nouns in student output is as high as 195 and the noun verb ratio is 14:1. Thus, the high noun-verb ratio here was partly due to the teacher questions and the lesson objectives. The questioning approach used in these two excerpts were coded as *association of key words and phrases,* which constitutes 13.5% of the total number of teacher questions in the 30 lessons and thus to a small degree played a visible role in the noun-oriented nature of the student output. The results of teacher question types will be presented later in Section 4.1.11 Teachers' questioning approaches.

4.1.9 The use of IRF sequences

Another crucial parameter of classroom interaction analyzed is the use of extended IRF sequences as compared to short single-cycled IRF sequences.

4.1.9.1) Average

The average number of IRF sequences of various lengths, e.g., one-cycled, two-cycled, in a lesson is shown in Figure 17 below. The average numbers were obtained through adding up the number of IRF sequences of different lengths in each lesson and dividing the sums by 30. Figure 17 below demonstrates the averages.

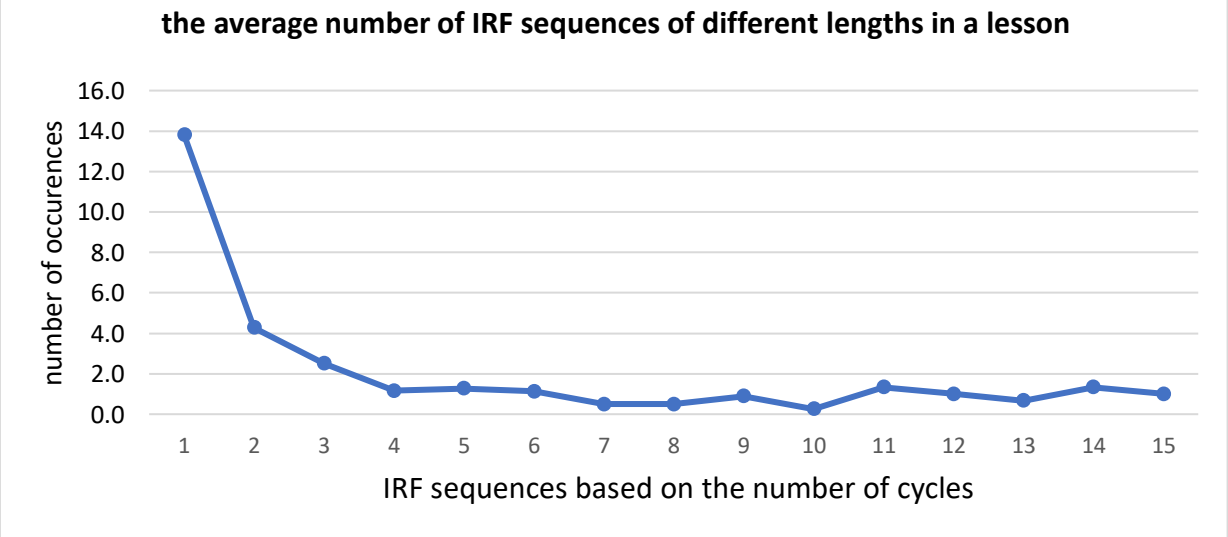


Figure 17 the average number of IRFs sequences of various lengths in a lesson

On average there were 13.8 single-cycled IRF sequences in a lesson, taking almost half of all IRF sequences. Single-cycled IRFs were much more frequently used than IRFs of any other lengths. The next most frequently used length of IRFs were two-cycled ones, on average 4.3 times per lesson, and then three-cycled ones, 2.5 times per lesson. The longer IRF sequences were rather rare, taking place only once or less than once per lesson on average.

To illustrate what the typical single-cycled IRFs were like in this research, two examples are given below in Excerpts 14 and 15, taken from Chris's first Physics lesson.

Excerpt 14

Turn	Timespan	Content	Speaker	IRF
6	0:26.5 - 0:28.2	Jerry, what's a prism?	T	T-I (1)
7	0:28.2 - 0:29.4	I don't know.	S	S-R (1)
8	0:29.4 - 0:45.0	You don't know? Prism is this shape here. Remember? Looks like this [T was using hand gesture to show a triangle shape], puts light into a rainbow. Triangular shape? That's a prism.	T	T-F (1)

Excerpt 15

Turn	Timespan	Content	Speaker	IRF
30	10:30.0 - 10:40.0	Which one will refract most? Well, obviously the one with the highest indices of refraction. Which one is the highest?	T	T-I (1)
31	10:40.8 - 10:42.2	*2.30*	S	S-R (1)
32	10:42.2 - 11:00.0	Here is your answer. So, 2.30 refracts the most. Why? Because as you remember, 2.3 means that light travels through this medium the smallest, so it bends the most. So, it has the highest ...[inaudible].	T	T-F (1)

In Excerpt 14 above, the student did not know the answer and the teacher provided it directly. In Excerpt 15, one student gave the correct answer and the teacher repeated the answer and provided the reason himself, i.e., '*Why? Because as you remember, 2.3 means that light travels through this medium the smallest, so it bends the most. So, it has the highest ...[inaudible]*'. Here the teacher did not ask the students to explain why the answer was 2.30, which could have been a case of extended IRF sequence where students' reasoning behind could be elicited.

4.1.9.2) Variation

To examine the variation of the use of IRF sequences in the 30 lessons, the variation of the percentage of single-cycled IRF sequences to all IRF sequences in each lesson was used as an indicator. This was because it was difficult to examine the variation of IRF sequences of all lengths (e.g., one-cycled, two-cycled, three-cycled etc,). The percentage of single-cycled IRF sequences can show at least how widely the short single-cycled IRFs were used across the 30 lessons, which can also indirectly reflect the proportion of all the multi-cycled IRFs. Percentages were used rather than absolute numbers because the absolute numbers of IRF sequences could be influenced by the lesson design and the amount of teacher-whole class interaction time in a lesson.

The percentage of single-cycled IRFs in each lesson is given in Table 31 below.

No.	Name	Number of single-cycled IRF s	Total number of IRF sequences	Percentage of single-cycled IRFs
1	Edward 1st lesson	16	29	55.2%
2	Edward 2nd lesson	0	0	0.0%
3	Christina 1st lesson	3	10	30.0%
4	Christina 2nd lesson	3	14	21.4%
5	Chad 1st lesson	26	29	89.7%
6	Chad 2nd lesson	11	17	64.7%
7	Colin 1st lesson	1	8	12.5%
8	Colin 2nd lesson	8	9	88.9%
9	Emma 1st lesson	19	23	82.6%
10	Emma 2nd lesson	4	8	50.0%

11	George 1st lesson	36	74	48.6%
12	George 2nd lesson	21	47	44.7%
13	Hannah 1st lesson	28	33	84.8%
14	Hannah 2nd lesson	11	16	68.8%
15	Jenny 1st lesson	33	48	68.8%
16	Jenny 2nd lesson	11	16	68.8%
17	Johnson 1st lesson	6	11	54.5%
18	Johnson 2nd lesson	5	12	41.7%
19	Kate 1st lesson	7	12	58.3%
20	Kate 2nd lesson	18	28	64.3%
21	Mat 1st lesson	9	11	81.8%
22	Mat 2nd lesson	7	11	63.6%
23	Lennon 1st lesson	10	31	32.3%
24	Lennon 2nd lesson	34	73	46.6%
25	Louis 1st lesson	10	14	71.4%
26	Louis 2nd lesson	18	20	90.0%
27	Nicolas 1st lesson	17	30	56.7%
28	Nicolas 2nd lesson	22	40	55.0%
29	Stella 1st lesson	3	17	17.6%
30	Stella 2nd lesson	17	27	63.0%
	average	**13.8**	**31.6**	**43.7%**
	standard deviation	**10.1**	**29.5**	**23.50%**

Table 31 percentage of single-cycled IRFs in each lesson

It needs to be noted that in Aaron's second lesson there were actually no IRF sequences at all as the lesson was made up with one teacher monologue, and then group discussion and non-content related talk. While there were also a few cases where single-cycled IRF sequences took up a lower percentage (e.g., Christina's two lessons, Colin's first lesson, Stella's first lesson), in most lessons the number of single-cycled IRFs was consistently above 40% of all the IRF sequences. More than half of the lessons also had more than 50% of the IRF sequences being single-cycled ones.

In summary, the result about the variation of IRF sequences in the 30 lessons reinforces the argument that the extended IRF sequences were used to a limited degree in most of the lessons.

4.1.9.3) IRF cycles started by repetition or reformulation of questions

While examining the occurrences for IRF sequences of various lengths, an interesting feature emerged. As specified in Chapter 3 Methodology, it seems that teachers repeated or reformulated their questions frequently, as a result of no responses from students, responses indicating difficulties of comprehending the question, or incorrect responses from the students. Thus, IRF cycles initiated by a repetition or a reformulation of a previous question were commonly found in extended IRF sequences. An example is also given in Appendix 14.

The frequency of these cycles in each lesson can be found in Table 32 below. The darkened rows, marked as R, means the cycles that were initiated by a repetition or a reformulation of the previous question. For example, the number 5 under '2-cycled' of Aaron's first lesson means there were five two-cycled IRF sequences in this lesson. The number in the R row below, '1', means there was one teacher initiation coded as 'T-I (2) R' in this lesson and this T-I (2) R could be in any IRF sequence longer than two cycles.

No.	Name	1-cycled	2-cycled	3-cycled	4-cycled	5-cycled	6-cycled	7-cycled	8-cycled	9-cycled	10-cycled	11-cycled	12-cycled	13-cycled	14-cycled	15-cycled
1	Edward 1st lesson	16	5	4	2	0	0	1	1							
	R		1													
2	Edward 2nd lesson	0														
3	Christina 1st lesson	3	3	2	0	2	1									
4	Christina 2nd lesson	3	7	3	1	1	1	0	0	1	0	0				
	R		7	3	1			1								
5	Chad 1st lesson	26	0	0	1	1	0	0	0	1						
	R	1	1													
6	Chad 2nd lesson	11	4	1	0	0	0	0	1							
7	Colin 1st lesson	1	5	1	1											

	R		1	1												
8	Colin 2nd lesson	8	0	0	1											
9	Emma 1st lesson	19	0	3	0	1										
	R		3	1	1											
10	Emma 2nd lesson	4	2	2												
	R		1	1												
11	George 1st lesson	36	9	15	6	4	2	1	1	0	1					
	R	2	9	5	2	2	2									
12	George 2nd lesson	21	7	5	1	1	6	2	0	1	0	2	0	0	0	1
	R		10	9	7	6	3	1	2	2	1	2	1	1		1
13	Hannah 1st lesson	28	1	2	1	0	0	0	0	1						
	R		1	2												
14	Hannah 2nd lesson	11	2	2	0	0	0	0	0	1						
	R		3				1			1						
15	Jenny 1st lesson	33	12	3												
	R		1	1												
16	Jenny 2nd lesson	11	2	2	0	0	0	0	0	1						
17	Johnson 1st lesson	6	2	1	1	1										
	R		2													
18	Johnson 2nd lesson	5	3	2	2											
	R		2	2	2											
19	Kate 1st lesson	7	2	2	0	1										
20	Kate 2nd lesson	18	5	2	2	0	1									
	R	3	3	5	2											

21	Mat 1st lesson	9	2													
	R		1													
22	Mat 2nd lesson	7	1	2	0	1										
	R	1	1	1						1						
23	Lennon 1st lesson	10	4	0	3	6	0	2	0	1	0	0	3	0	2	
	R		2	1	1											
24	Lennon 2nd lesson	34	18	4	3	4	2	1	0	1	0	2	0	2	2	
	R		2													
25	Louis 1st lesson	10	2	0	0	0	2									
26	Louis 2nd lesson	18	0	1	1											
	R	1	1													
27	Nicolas 1st lesson	17	5	1	2	0	2	0	3							
28	Nicolas 2nd lesson	22	8	8	0	2										
	R		1	2												
29	Stella 1st lesson	3	10	0	2	2										
30	Stella 2nd lesson	17	6	2	0	1	1									
	R	1	4	1	1		1	1								

Table 32 the number of IRF cycles initiated by repetitions or reformulations in each lesson

To have a more straightforward understanding of the degree to which repetitions and reformulations occurred, the total number of repetitions and reformulations in each lesson is given in Table 33 below. These numbers are a sum of all the repetitions and reformulations in that lesson and do not differentiate at which cycle of an IRF sequence the repetitions or reformulations took place.

No.	Name	Total number of repetitions and reformulations
1	Edward 1st lesson	1
2	Edward 2nd lesson	0
3	Christina 1st lesson	0
4	Christina 2nd lesson	12
5	Chad 1st lesson	2
6	Chad 2nd lesson	0
7	Colin 1st lesson	2
8	Colin 2nd lesson	0
9	Emma 1st lesson	5
10	Emma 2nd lesson	2
11	George 1st lesson	22
12	George 2nd lesson	45
13	Hannah 1st lesson	3
14	Hannah 2nd lesson	5
15	Jenny 1st lesson	2
16	Jenny 2nd lesson	0
17	Johnson 1st lesson	2
18	Johnson 2nd lesson	6
19	Kate 1st lesson	0
20	Kate 2nd lesson	13
21	Mat 1st lesson	1
22	Mat 2nd lesson	4
23	Lennon 1st lesson	4
24	Lennon 2nd lesson	2
25	Louis 1st lesson	0
26	Louis 2nd lesson	2
27	Nicolas 1st lesson	0
28	Nicolas 2nd lesson	3
29	Stella 1st lesson	0
30	Stella 2nd lesson	6
	average	**4.8**
	standard deviation	**9.0**

Table 33 the number of repetitions and reformulations in each lesson

As can be seen, apart from just a few lessons, there were often one to five IRF cycles in a lesson initiated by repetitions or reformulations of a previous question. On average, there were 4.8 repetitions or reformulations of questions in a lesson. However, there was a rather large standard deviation, 9.0. This could be explained by the few lessons with a particularly high number of Rs. These lessons are George's two lessons, Christina's second lesson and Kate's second lesson. In

these four lessons, the teachers repeated or reformulated their questions frequently. For example, George's second lesson had 45 of them.

The results overall indicate that there was a small but consistent presence of repetition of questions or reformulation of questions from teachers in this research. Considering the already low number of extended IRF sequences in most lessons, this means that the actual extended chains of IRFs where different follow-up questions were asked were even rarer.

The consistent occurrences of repetitions and reformulations also reflects the difficulty in these EMI science classes to get messages across and move forward dialogues. Excerpt 16 below provides an example of the situation where students seemingly failed to comprehend the teacher's question accurately, leading to the teacher's reformulation of the question. This excerpt took place in George's first Biology class where the teacher was asking students to discover the component that makes the 22 types of amino acids different. The drawings of the structure of different amino acids were also on the board.

Excerpt 16

Turn	Timespan	Content	Speaker	IRF
13	2:08.0 - 2:27.6	Ok, so what's the difference? There are 22 amino acids. What's the only thing that is different? Lucy, what's the only thing that is different about amino acid?	T	T-I (3)
14	2:27.6 - 2:31.4	Em....different?	Lucy	S-R (3)
15	2:31.4 - 2:32.8	What's the difference? So, so these parts *[T pointing at the drawing about the structure of amino acids on the blackboard.]*	T	T-I (4) R
16	2:32.8 - 2:35.6	[wait time]		WT after T-I
17	2:35.6 - 2:36.5	Ah, the nitrogen?	Lucy	S-R (4)
18	2:36.5 - 2:39.2	The nitrogen is different? [T pointing at N]	T	T-I (5)

19	2:39.2 - 2:41.5	Maybe?	Lucy	S-R (5)
20	2:41.4 - 2:42.8	What's the difference?	T	T-I (6) R
21	2:42.8 - 2:43.6	Different?	Lucy	S-R (6)
22	2:43.6 - 2:46.3	There are 22 amino acids, right?	T	T-I (7)
23	2:46.3 - 2:47.0	Yeah.	Ss	S-R (7)
24	2:47.0 - 2:54.7	What's different about, what makes these 22 amino acids different, if everything here is the same [T pointing to the drawing]?	T	T-I (8) R
25	2:54.7 - 2:59.2	Ohhh! The different order of... [S looking down at the textbook]. The R group.	Ss	S-R (8)
26	2:59.2 - 2:59.8	What?	T	T-I (9)
27	2:59.8 - 3:00.9	The R group.	S	S-R (9)
28	3:00.9 - 4:20.0	The R group, the R group on the side chain. So here it would be a R group, or this is a side chain [T drawing], meaning that, ok, so if there was, ok [T drawing, screenshot], there is an H, right? This is a Glycine. Or, it could be something like, [T drawing], so R group, the H could be a hydrogen, could be a, an acid, or other stuff, so it's always changing, a completely different R group for each amino acid. So, there are 22 different side chains.	T	T-F (9)

Excerpt 16 above shows that the teacher repeated and reformulated the question '*what's the only thing that is different about amino acid?*' three times in this incident of negotiation of meaning until the students accurately understood the meaning of this question. The difficulty here probably lies in the students' problem with comprehending the use of '*different about*' in this question or the use of a relative clause '*that is different about amino acid*' to describe the noun phrase '*the only thing*'. This case of negotiation of meaning was resolved until the teacher's paraphrasing of the question into '*what makes these 22 amino acids different, if everything here is the same?*' This example reveals the difficulty with the medium of instruction as an L2 to get

messages across and it seems much more delicate effort and strategies from the EMI teachers are required to modify their questions repeatedly based on students' reactions. These processes mean the exchange of ideas between teachers and students can probably take significantly longer than in the L1 classrooms.

Another example below, Excerpt 17, demonstrates the situation where students did not provide any responses. This excerpt is from Kate's second Biology lesson about different types of biomes. This dialogue took place during an activity where students were asked to come up with the similarities and differences of two given biomes. The two biomes being compared here are tundra and permanent ice.

Excerpt 17

Turn	Timespan	Content	Speaker	IRF
48	8:48.0 - 8:54.0	Why do you think the permanent ice has a higher temperature? Anybody?	T	T-I (1)
49	8:54.0 - 8:57.0	[wait time]		Wait time after T-I
50	8:57.0 - 9:03.0	If you look at the information there, why, why is the ice part warmer?	T	T-I (2) R
51	9:03.0 - 9:07.0	[wait time]		Wait time after T-I
52	9:07.0 - 9:10.0	Because it has more what?	T	T-I (3) R
53	9:10.0 - 9:15.0	[wait time]		Wait time after T-I
54	9:16.0 - 9:18.0	Anybody, anybody in the class?	T	T-I (4) R
55	9:18.0 - 9:20.0	[wait time]		Wait time after T-I
56	9:21.0 - 9:23.0	Or, sunshine, sunshine!	S5	S-R (4)
57	9:23.0 - 9:28.0	Err, it could be, but not, because the latitude is higher, so no.	T	T-F (4)

In Excerpt 17 above, the teacher reformulated the question '*Why do you think the permanent ice has a higher temperature? Anybody*?' three times after eliciting no responses from the students. This is another common situation where repetitions and reformulations took place, which is when there were no responses. It also demonstrates the fact that teachers often spent considerable time in restating the same questions in different ways to elicit responses from students and move forward the conversation.

4.1.10 Language focused episodes (LFEs)

As explained in Section 3.5.2.6 in Chapter 3 Methodology, the periods of lessons where the teacher diverted their students' attention explicitly from the content plane to the language plane were coded as 'language-focused episodes' (LFEs). In LFEs, the teacher explained certain language structures explicitly.

4.1.10.1) Average

The average time percentage of the LFEs in a lesson is shown in Figure 18 below.

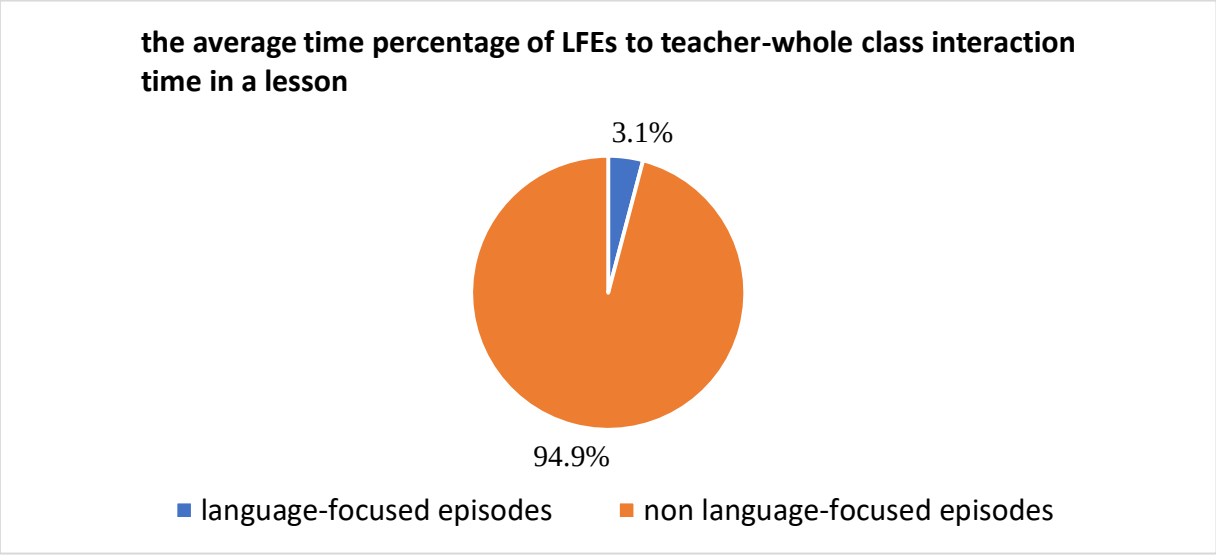


Figure 18 average time percentage of LFEs in a lesson

Figure 18 above shows that on average LFEs occupied 3.1% of the teacher-whole class interaction time in a lesson. Overall there was a total of 47.1 minutes of LFEs in the 30 lessons and the average time length was 1.6 minute per lesson. Again, the percentage was against the interaction time rather than the overall lesson time to eradicate the influence of the use of different activities. The results show that explicit focus of the language aspect in the EMI science lessons in this study took a rather small proportion of the interaction time. The content of the LFEs will be presented in detail in Section 4.1.10.3) Content of the LFEs later.

4.1.10.2) Variation

The time lengths of LFEs and the percentages they took of the teacher-whole class interaction time in each lesson is given below in Table 34.

no.	lessons	length (mins)	percentage of interaction time
1	Edward 1st lesson	0.0	0.0%
2	Edward 2nd lesson	0.0	0.0%
3	Christina 1st lesson	2.0	7.2%
4	Christina 2nd lesson	1.9	11.7%
5	Chad 1st lesson	2.5	8.3%
6	Chad 2nd lesson	1.6	6.1%
7	Colin 1st lesson	13.0	36.3%
8	Colin 2nd lesson	2.5	8.7%
9	Emma 1st lesson	0.0	0.0%
10	Emma 2nd lesson	0.0	0.0%
11	George 1st lesson	2.3	7.5%
12	George 2nd lesson	0.1	0.2%
13	Hannah 1st lesson	0.0	0.1%
14	Hannah 2nd lesson	0.1	0.9%
15	Jenny 1st lesson	0.7	2.6%
16	Jenny 2nd lesson	0.0	0.0%
17	Johnson 1st lesson	0.0	0.0%
18	Johnson 2nd lesson	1.2	2.8%
19	Kate 1st lesson	0.0	0.0%
20	Kate 2nd lesson	2.7	7.0%
21	Mat 1st lesson	0.0	0.0%
22	Mat 2nd lesson	1.4	4.3%
23	Lennon 1st lesson	1.9	4.6%
24	Lennon 2nd lesson	0.0	0.0%

25	Louis 1st lesson	0.0	0.0%
26	Louis 2nd lesson	0.0	0.0%
27	Nicolas 1st lesson	0.0	0.0%
28	Nicolas 2nd lesson	0.4	1.9%
29	Stella 1st lesson	3.3	9.5%
30	Stella 2nd lesson	1.2	3.9%
	average	**1.6**	**3.1%**
	standard deviation	**1.47**	**7.1%**

Table 34 time percentage of LFEs in each lesson

As can be seen in Table 34 above, the majority of the lessons had a low percentage of LFEs, with a small number of outliers. For example, 36.3% of the interaction time in Colin's first lesson was LFEs. This was because a large proportion of this lesson was dedicated to the teacher explaining a list of key vocabulary given on a vocabulary worksheet to the students. The purpose of it, as explained in the pre and post lesson interviews with the teacher, was to clear up the difficult words in the new chapter before the teacher started teaching the science content of it.

Having discussed the overall low presence of LFEs and the occasional exceptional cases, it needs to be reiterated again that these results only included the lesson time periods when there was explicit teaching of language. As explained in Chapter 3 Methodology, the implicit focus on the language aspect was not coded, e.g., the use of recast during negotiation of meaning between a teacher and students, which also creates opportunities for language acquisition (Long, 1996). This means that the LFEs do not represent all the opportunities there were in the 30 lessons for language learning.

4.1.10.3) Content of the LFEs

Three domains of linguistic features addressed in the LFEs emerged - vocabulary, grammar and idioms. The vocabulary-focused LFEs include the teachers exploring the meaning of non-technical vocabulary, the non-science meaning of technical vocabulary (e.g., *conductor* on a train and c*onductor* for electricity), pronunciation, and spelling. The grammar-focused LFEs include the teachers exploring morphemes. The idiom-focused LFEs concern the teachers

explaining the meaning of idioms. The time length and percentage of each type of LFEs in the 30 lessons in total are presented in Table 35 below.

Types of LFEs		length in minutes	percentage in the overall LFEs
Vocabulary-focused LFEs	meaning of non-technical vocabulary	31.4	66.7%
	the non-science meaning of technical vocabulary	3.2	6.9%
	pronunciation	1.8	3.9%
	spelling	1.1	2.4%
Grammar-focused LFEs	morpheme	9.0	19.1%
Idiom-focused LFEs	idiom	0.5	1.1%
Total		47.1	100.0%

Table 35 quantity of each type of LFEs in 30 lessons

Most of the LFEs concerned vocabulary, with the meaning of non-technical vocabulary occupying 66.7% of the total time of LFEs. 6.9% of LFEs introduced the everyday meaning of technical vocabulary by differentiating it from its scientific meaning. Morpheme was the second most prominent type, occupying 19.1% of the overall LFE time.

Examples of the different types of LFEs are given below.

4.1.10.3.1). Vocabulary-focused LFEs

a. Meaning of non-technical vocabulary

Explanation of non-technical vocabulary was frequently observed in this study, occupying as much as 66.7% of the time length of all LFEs. Examples include *spread, strip, potential, shimmering, neutral, hose, anchor, blend, separate, enhance, reverse, erupt, substance, transfer, indicate, conserve, equivalent, frigid, display, combine, universe* and so on. While some of them are everyday non-academic vocabulary, such as *hose, shimmering, anchor, strip, erupt*, some are in the Coxhead's (2000) academic word list, such as *enhance, neutral, reverse, transfer.* Very

often the teachers initiated the explanation through comprehension checks (e.g., 'do you know the meaning of XX?). As these comprehension checks emerged as a rather noticeable type of teacher questions from the lesson observation data, they were also coded as '*vocabulary check questions*', as explained in Chapter 3 Methodology, and the frequency of them will be presented in Section 4.1.11 Teachers' questioning approaches in this chapter later.

Excerpt 18 is from Christina's first Biology lesson on sea floor spreading. In Excerpt 18, during the teacher's explanation of how sea floor spreading takes place, she paused the introduction of science content and used a comprehension check to see if students knew the word *eruption*, a case of teachers' explicitly diverting students' attention to the meaning of a non-technical word.

Excerpt 18

Turn	Timespan	Content (target word: eruption)	Speaker
10	16:53-17:38	Ok? So, the main thing is that you can know this information right here *[Teacher pointing at a specific paragraph in the textbook]* because it is going to relate to sea floor spreading. Ok? So, sea floor spreading is proposed by um a scientist named Harry Hess from the United States of America. And basically, he realized that the earth is like a big bar magnet with magnetic waves surrounding it. So just like the picture that I've showed you earlier, kind of like that. Ok? Um he also knew that the ocean floor was being formed from eruptions under the sea. Now what's, what does the word eruption mean?	T
12	17:39 - 17:41	[wait time]	
13	17:42 - 17:48	Eruption means to? What does this word mean?	T
14	17:48 - 17:49	Burst.	S2
15	17:49 - 17:52	To Burst, yeah! To burst. To erupt. [Teacher using hand gestures to show "burst" and "erupt"]	T
16	17:52 - 18:14	Ok? Um because Harry has um knew that there's an eruption in the ocean floor. Uhm, this eruption is producing magma.	T

Here, the teacher was explicitly checking students' understanding of the word *erupt* and Student

2 was able to provide a synonym *burst*. To L1 students, *erupt* is probably a common word that they encounter outside of the science context and thus may not need an explicit semantic explanation. However, because of the EMI students' L2 language needs, such non-technical vocabulary was observed to be often explained.

Excerpt 19 below is another example, which comes from Stella's first Biology lesson on the structure of plants. This is a rare case of student-initiated LFEs as opposed to the common case of teacher-initiated ones. Here, a student interrupted the teaching of the science content and raised a clarification request. In response, the teacher provided a lengthy explanation about the non-technical word *anchor*.

Excerpt 19

Turn	Timespan	Content	Speaker
5	2:39.0 - 2:59.0	So for roots, it is a plant part, a part of a plant. This is the part that is typically, usually below the ground that often we cannot see. Some cases we can, though. [read aloud from the slides] *"They absorb water and dissolve minerals. It helps to anchor the parts that are above the ground, like the shoot system. And they often store food."* So the root system is a very important part of plants. [T paused for 10 seconds for students to comprehend].	T
6	2:59.0 - 2:59.5	Ms Steele?	S1
7	2:59.5 - 3:00.2	Yes	T
8	3:00.2 - 3:03.6	What is, emm, anchor? What's that?	S1
9	3:03.6 - 3:04.7	Anchor?	T
10	3:04.7 - 3:05.7	Yes.	S1
11	3:05.7 – 5:21.0	So, anchor means to, well, first, you can have a boat anchor. [T drew on the blackboard] So you drop it off the boat, it goes into the water, and it keeps your boat in one spot. An anchor is something that holds another object down. So to anchor a boat, you are holding it, you are keeping it in one spot by dropping an object that is very heavy into the water. It sinks to the bottom, it sits on the sand, and it holds your boat in that one spot. So this could be the sand. So when you drop, your boat's anchor is attached to a very long rope. A machine lets the anchor go into the water. It sits on the sand, and it's strong enough to keep your boat in this area. So that you can either stop and fish, you can get out of your	T

		boat to go around, and your boat won't float away. So for a root system, the roots help anchor the pieces above the ground to the soil, to another tree. [T drew a flower on the blackboard and pointed to it as speaking] We have a flower. Here is the ground. You have your roots. These roots are going to help anchor this flower to the ground. So it's going to anchor the flower to help keep the flower in one spot. Without the roots, the flower is not going to be able to stay in the soil. It can fall. It can be blown away by the wind. So these roots keep it planted in the soil, in the ground.	
14	5:21.0 - 5:23.6	Does that make more sense?	T

In Excerpt 19 above, a student initiated a question about the meaning of *anchor*, a non-technical word used in the teacher's definition of a biology concept, roots, in Turn 5. The teacher used a variety of input modification techniques that are often found in negotiation of meaning instances where communication breakdown occurs among interlocutors involving at least one nonnative speaker, e.g., exemplifying, drawing, paraphrasing. This is a process that has been extensively researched to be beneficial for L2 acquisition (Long, 1996; Pica, Young, & Doughty, 1987). Again, it is speculated that in L1 non-EMI classes, the word *anchor* would probably be a known word to students at the high school level and teachers probably would not need to explain it, particularly not at this level of detail.

It is also interesting that while this lexical LFE took up two and a half minutes, a direct Chinese equivalent exists, which is '锚', with the same literal and figurative meaning as the English word has. A bilingual teacher would have been able to provide it. On the other hand, this example of negotiation for meaning would not have occurred if the direct equivalent had been immediately given.

b. The non-science meaning of technical vocabulary

Apart from the instruction on the meaning of non-technical vocabulary, it was also found that, when a science term has an everyday non-science meaning, the everyday sense was sometimes also explained to the students. This type of LFEs made up a rather small proportion of 6.9% of

all LFEs. Examples include teacher's explanation of the everyday meaning of '*conductor*' as in train conductor when introducing the science concept of conductor, the explanation of the everyday meaning of '*insulate'* (i.e., trapping heat) when introducing the science concept of insulator and so on. Excerpt 20 below comes from Colin's first Physics lesson where the teacher was introducing a list of new lexical items for the next chapter on Electrostatics. Here, the teacher provided a monologue to explain the meaning of *charged objects* where he explicitly explained the everyday meaning of *charge* with an example.

Excerpt 20

Turn	Timespan	Content (target word: charge)	Speaker
20	5:38.0 - 6:23.0	Charged objects---let's talk about it---charged object. What does charge mean to you? That means when your father gives you his credit card, and you go to stores, go into the stores, shopping, and you're charging on the credit card. You know? You don't get to use a credit card? This is a different kind of charge, yes? Well uh we'll learn more about it, but a charged object is an object that has an electrical charge and electrical field. It has more electrons than protons or less electrons than protons. We'll get to the idea of it but it has an electrical charge, positive and negative.	T

In this LFE in Excerpt 20 above, the teacher explained the non-science meaning of *charge* through an everyday example of using a credit card, contextualising it through repetition and paraphrasing (e.g., *go to stores, go into stores, shopping*). Again, this demonstrates some input modification techniques which are often used in both instructional and naturalistic conversations to make input more comprehensible to non-native speaking interlocutors (Ellis & He, 1999). It is speculated that, although explicit instruction to distinguish everyday meaning and science meaning of technical vocabulary is also important for English L1 students, explanations of everyday meaning may need to be more explicit and detailed for EMI students. This issue of clarifying the everyday meaning may also be more pressing in the EMI context where students may not be aware of the polysemous nature of certain technical vocabulary and thus not aware of the distinction.

c. Pronunciation

With 3.9% of the LFEs concerning pronunciation, Excerpt 21 below provides an example taken from Kate's second Biology lesson on the characteristics of different types of biomes. The context of this excerpt is that the class was asked to compare two given biomes. The student here was presenting his idea on the similarities between tundra and permanent ice.

Excerpt 21

Turn	Timespan	Content (content word: permanent)	Speaker
10	1:45.0 - 1:56.0	First of all, the same(similarity) of the tundra and perman…preman…	S5
11	1:56.0 - 1:57.0	Per-man-nent. Good.	T
12	1:57.0 - 2:29.0	Permanent ice. Em…first of all, their…em…location [wait for 8 seconds] They are both at the frigid zone. [S6 writing 'at the frigid zone' on the blackboard]	S5

In Excerpt 21 above, the student was having difficulty in pronouncing the word *permanent*, an everyday non-technical word. The teacher provided the correct pronunciation with pauses between syllables to make it clear to the student, who then repeated the correct pronunciation. Again, this recast appears to be a decision by the teacher on the basis of the student being in an EMI context. Whether he was just trying to scaffold the communication, i.e., helping it along, or whether he was concerned with ensuring that mis-pronunciation would not happen again, we do not have sufficient evidence to provide a definitive answer.

d. Spelling

2.4% of the total LFEs in the 30 lessons focused explicitly on the spelling of vocabulary. Excerpt 22 below comes from Colin's first Physics lesson where he was going through a list of key vocabulary for the next chapter and focused on both the meaning and the spelling of *vary* and *very*.

Excerpt 22

Turn	Timespan	Content (target word: variable)	Speaker
17	13:20.0 - 13:35.0	If somebody needs constant, what is it? If it's constant? Is this the same---can you give me an opposite of constant? A word? A single word that would be an opposite of constant? What? We've had independent and responding---	T
18	13:35.0 - 13:36.0	Variable.	S1
19	13:36.0 - 13:50.0	Variables. Very good. That comes from the word vary. Not V-e-r-y, meaning a lot of, but v-a-r-y, to change. Ok?	T

In turn 19 of Excerpt 22 above, the teacher showed his awareness that the two non-technical words, *vary* and *very*, may be confusing to the L2 students due to either the distinction between the two vowels in the written form or the subtle distinction in the two phonemes. Apart from the focus on spelling, this LFE also contains the teacher's comprehension check on students' understanding of the meaning of *constant*.

4.1.10.3.2). Grammar-focused LFEs

In the grammar-focused LFEs, attention to morphemes is the only type that was found.

a. Morphemes

Morphemes were the second largest type of LFEs in this study, occupying 19.1% of the total LFEs. The morphemes that were addressed are mostly prefixes and suffixes in technical science vocabulary. Excerpt 23 comes from George's first Biology lesson on the topic of chemicals of life (e.g., carbohydrates, lipid and protein). In this case, the teacher was focusing on the meaning of prefixes.

Excerpt 23

Turn	Timespan	Content (target morphemes: poly, mono)	Speaker
210	18:30.9 - 18:38.0	So Poly means what, Kathleen? "Poly" means what?	T
211	18:38.0 - 18:42.9	Er, something mixed together.	Kathleen
212	18:42.9 -	Mixed together? "Poly" means many,	T

	18:47.0		
213	18:47.0 - 18:49.2	Mono means what?	T
214	18:49.2 - 18:49.9	One, one.	S1
215	18:49.9 - 18:57.0	One. Ok, so polymer is made of many monomers.	T

It could be argued that the morphemes also constitute the meaning of the science terms and thus these LFEs should be seen as content-focused. However, the meaning of prefixes and suffixes are not limited to the science terms but are linguistic knowledge that could be applied to other vocabulary outside of science learning, e.g., the use of *mono* in *monolingual*. It is an interesting question to ask whether the meaning of *poly* and *mono* would be common knowledge to L1 students at the high school level.

4.1.10.3.3). Idiom-focused LFEs

Explanations of idioms were also present in this study. In Excerpt 24 from Colin's second Physics lesson, the students were given scissors and tape to conduct an experiment in pairs on how friction separates changes. They were just starting a new chapter on Electrostatics.

Excerpt 24

Turn	Timespan	Content (target idiom: don't run with scissors)	Speaker
40	20:11.0 - 21:30.2	[Teacher handing out scissors and tapes to students.]	T
41	21:30.2 - 21:33.1	Don't run with scissors. Don't run with scissors. Can you figure out what that means?	T
42	21:33.1 - 21:35.0	Uh, you will hurt yourself.	S8
43	21:35.0 - 22:01.0	You can hurt yourself, yes. If you fall down on the scissors and they are sharp, right, you could hurt yourself. And that's the literal meaning. But the figurative meaning, I don't know if you use the words in Chinese, is, be careful. Just be careful. Doesn't mean you might not even have scissors, right? But you say I am going to talk to my Chinese literature teacher and I am going to tell him what I think. I might say, be careful, don't run with scissors.	T

In Excerpt 24 above, the teacher, who is from Canada, introduces the meaning of the idiom, *don't run with scissors* (which also means 'be careful' generally). It is interesting that this is one of the very few instances in the corpus that the teacher actually wondered what the phrase might be in Chinese in order to make a local contact with the students. Again, we note that this LFE is not directly related to the science teaching.

It is also interesting to point out that the teacher used not only an inner circle idiom (Kachru, 1984), but also one that is typically used in Canada. This example also reflects that, given the variety of English that exists in different regions of the world, the EMI students could be exposed to a particular variation of English, especially the non-academic use of English, depending on the background of the teacher.

4.1.11 Teachers' questioning approaches

Teachers' use of questioning is an important component of teacher-student interaction and it plays a significant role in the constructivist approach of teaching (Hohenstein & Manning, 2010), as elaborated before. In this section, the results about teachers' use of questions will be presented at two levels :1) teachers' use of questions overall; 2). teaches' use of different types of questions.

4.1.11.1) Teachers' use of all questions

On average 54.1 questions were asked by the teacher in one lesson and there was one teacher question every 47.0 seconds during teacher-whole class interaction time. The repetition and reformulation questions were also included in the counting of teacher questions.

The number of all teacher questions (regardless of the types) in each lesson is given in Table 36 below. The first column in the table is the number of teacher questions. The second one, '*average time interval between two questions during interaction time*', measures how often teachers asked questions during teacher-whole class interaction time, demonstrated by the average time interval between teacher questions.

no.	lessons	no. of questions	average time interval between two questions during interaction time (seconds)
1	Edward 1st lesson	65	28.5
2	Edward 2nd lesson	0	n.a.
3	Christina 1st lesson	48	35.5
4	Christina 2nd lesson	39	24.8
5	Chad 1st lesson	66	31.8
6	Chad 2nd lesson	29	54.6
7	Colin 1st lesson	43	60.4
8	Colin 2nd lesson	14	121.9
9	Emma 1st lesson	39	42.5
10	Emma 2nd lesson	21	73.5
11	George 1st lesson	169	10.8
12	George 2nd lesson	147	14.0
13	Hannah 1st lesson	56	29.8
14	Hannah 2nd lesson	31	22.6
15	Jenny 1st lesson	66	22.4
16	Jenny 2nd lesson	27	22.9
17	Johnson 1st lesson	22	107.1
18	Johnson 2nd lesson	30	84.8
19	Kate 1st lesson	26	20.6
20	Kate 2nd lesson	54	43.1
21	Mat 1st lesson	12	128.5
22	Mat 2nd lesson	18	108.6
23	Lennon 1st lesson	157	15.6
24	Lennon 2nd lesson	211	11.2
25	Louis 1st lesson	30	71.2
26	Louis 2nd lesson	29	73.6
27	Nicolas 1st lesson	37	42.0
28	Nicolas 2nd lesson	69	17.3
29	Stella 1st lesson	36	58.2
30	Stella 2nd lesson	33	61.5
	average	**54.1**	**47.0**
	standard deviation	**50.4**	**34.3**

Table 36 frequency of teacher questions in each lesson

Most of the lessons consistently had around 50 questions per lesson. Certain teachers used a significantly higher number of questions than others. For example, there were 169 and 147 teacher questions in George's two lessons, and 157 and 211 questions in Lennon's two lessons. On the other hand, there were zero teacher questions in Aaron's second lesson as 72% of the lesson time was students' own group discussion, 29 teacher questions in Colin's second lesson where 33% of the lesson was students doing a practical activity, and only 12 teacher questions in Mat's first lesson where 28% of the lesson time was occupied by the use of videos. This is to say that certain low use of teacher questions was partly due to the heavy use of non-interactive activities in their lessons. Apart from these cases of special use of lesson activities, however, the number of teacher questions was rather consistently around 50 across the 30 lessons.

4.1.11.2) Teachers' use of different types of questions

This section provides the results of teachers' use of different types of questions. Before delving into the results, it needs to be reiterated that the coding framework for teacher questions does not cover all the questions asked by the teachers in this study. The coding framework and the examples for each question type are given in Chapter 3 Methodology and Appendix 15, and are not repeated here.

The frequency of each approaches and types in the 30 lessons in total will be presented first, and then the variation of the frequencies across the lessons. Following the results measured by frequency, the time length of the whole dialogue where the questions were situated within will also be presented. As explained in Chapter 3, this was to reflect the rationale of the constructivist questioning approaches proposed in Chin's (2007) article, where the teachers' use of constructivist questioning approaches were seen as a discursive strategy and were identified considering the thinking reflected in the students' responses as the dialogue progressed. The unit of analysis for frequency is individual teacher questions. The unit of analysis for the time length of dialogues is individual dialogues where a certain questioning approach was situated within.

Explanations regarding the analysis are also given under Section 3.5.3.11 in Chapter 3 Methodology.

4.1.11.2.1) Frequency - Results of the 30 lessons in total

The number of teacher questions of different approaches and types, including constructivist and non-constructivist, and the frequency percentage of them to the total number of teacher questions in the 30 lesson is shown in Table 37 below.

Question types	**Number of occurrences**	**Percentage to the total no. of questions**
Questions considered as constructivist (coded using Chin (2007)'s framework)	**742**	**45.7%**
a.Socratic questioning	425	26.2%
• pumping	415	25.6%
• Constructive challenge	10	0.6%
• Reflective toss	0	0%
b.Verbal jigsaw	221	13.6%
• association of key words and phrases	220	13.5%
• verbal cloze	1	0.1%
c.Semantic tapestry	85	5.2%
• multi-pronged questioning	29	1.8%
• stimulating multi-model thinking	44	2.7%
• framing and zooming	12	0.7%
d.Framing	11	0.7%
• Question-based prelude	0	0%
• Question-based outline	11	0.7%
• Question-based summary	0	0%
Questions considered as non-constructivist (developed inductively in this research)	**340**	**20.9%**
a.Recall questions	165	10.2%
b.Direct comprehension check questions	89	5.5%
c.Vocabulary check questions	86	5.3%

Table 37 number and percentage of different types of teacher questions in 30 lessons

Figure 19 below gives a more visual presentation of the results above. The last three types, including vocabulary check questions, direct comprehension check questions and recalls, are the non-constructivist teacher questions that emerged from the data, and the rest are the constructivist questioning approaches that are identified in Chin's (2007) framework.

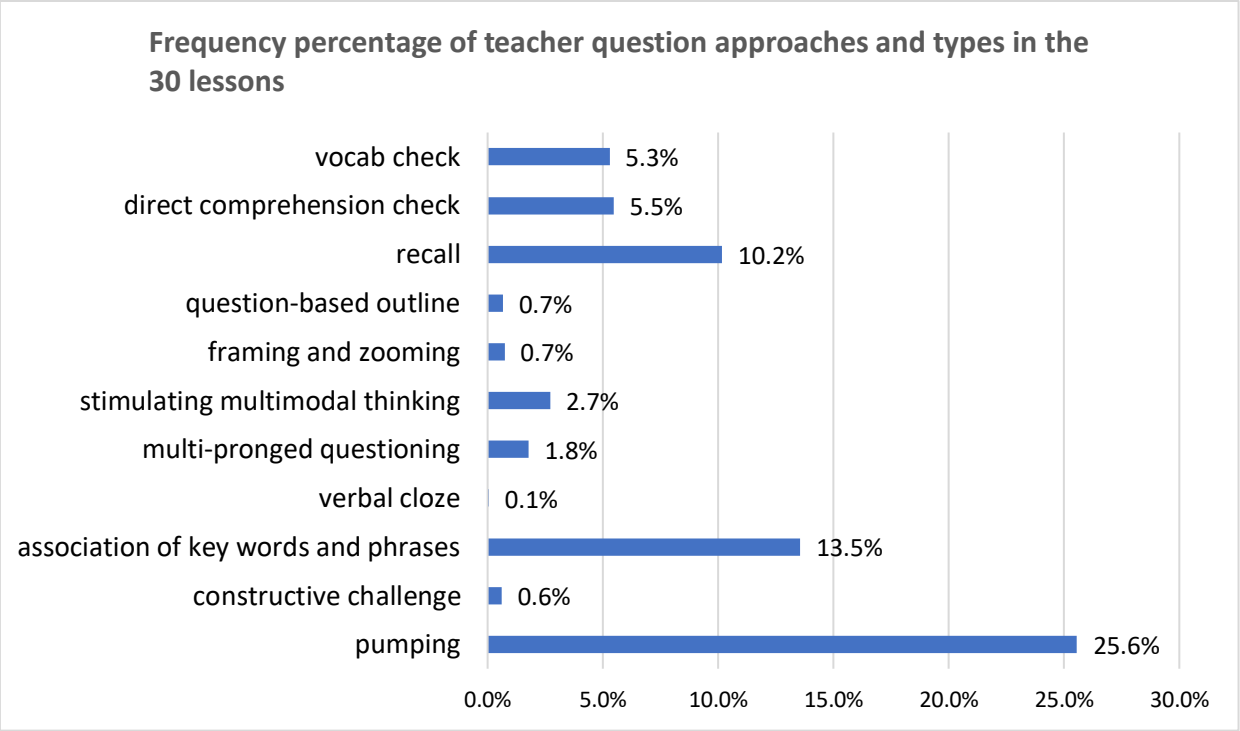


Figure 19 frequency percentage of different types of teacher questions in the 30 lessons

The results are described below for the constructivist teacher questions first and then the non-constructivist teacher questions.

a. The constructivist questions

As the diagrams above show, 45.7% of all the 1624 questions across the 30 lessons are considered among the four constructivist questioning approaches which promote productive thinking, as categorized in Chin's (2007) framework. 20.9% of all the questions were identified as the three newly added question types, which are considered as non-constructivist questions. This means that as much as almost half of all the teacher questions (i.e., 45.7%) could be considered as effort to encourage constructivist thinking, as defined by Chin's framework. The

rest 38.1% of all the teacher questions were neither in the Chin's framework or among the three non-constructivist question types.

Among the constructivist teaching approaches, *pumping* was the most widely used approach, occupying as much as 25.6% percent of all the questions teacher asked, followed by 13.5% of *association of key words and phrases*. This means that the teachers often tried to elicit information from the students and encouraged student talk rather than directly giving information to the students. The teachers also paid a fair amount of attention to reinforcing their students' understanding of the key technical vocabulary and thus helping them form coherent declarative science knowledge. In comparison, *multi-pronged questioning* and *stimulating multimodal thinking* were used much less, at a rate of as low as 1.8% and 2.7% among all the teacher questions. This means the teachers seldom used questions to lead students to address or understand issues from different angles or using different modalities, such as leading students to use mathematical calculation, drawing, real-life objects, etc. to understand one topic.

Apart from examining the relatively common questioning approaches, it is also important to look into the ones with a minimal presence or the absent ones. *Constructive challenge, framing & zooming,* and *question-based outline* were all scarcely used. Each of them makes up below 1% of all the teacher questions and each was asked about 10 times in all the 30 lessons. This shows that, for example, when students gave incorrect answers to a question posed by their teacher, the teacher rarely used the '*constructive challenge*' approach to ask students to re-think their incorrect answers and lead them to work out the correct answers on their own, rather than giving the corrective feedback directly. In addition, a few approaches in the Chin's (2007) framework were absent, e.g. '*reflective toss*' under the category of '*Socratic questioning*', '*verbal cloze*' under '*verbal jigsaw*', and '*question-based prelude*' and '*question-based summary*' under the '*framing*'. This means that, for instance, when students asked a question, teachers never used the '*reflective toss*' approach to ask the question back to the students, which demands students to reflect on their own questions and eventually assists students to figure out the answers themselves. Instead, most teachers gave the answers to students' questions immediately and directly.

Overall, the results show a clear picture that *pumping* was widely used, with the rest of the approaches all being rather exceptional than typical. As Chin (2007) discussed, each of the questioning approaches possesses a special and meaningful function in contributing to constructivist teaching. Thus, the limited diversity in the use of questioning approaches suggests a rather homogenous or monocultural style of questioning in promoting students' productive thinking in the lessons of this research.

b. The non-constructivist questions

As shown in Table 36 earlier, regarding the three question types that emerged through inductive data analysis, *recall*, *vocabulary check questions*, and *direct comprehension check questions* in total took up 20.9% of all teacher questions asked. Among them, *recall* questions were most frequently used, taking up 10.2% of all teacher questions and having occurred 165 times in the 30 lessons. *Direct comprehension check questions* and *vocabulary check questions* had a smaller presence. They respectively occupied 5.5% and 5.3% of all the questions and were asked 89 times and 86 times in total. Examples of each question types are given in Appendix 16 and are not repeated here.

To put it differently, the percentages of these question types mean that on average every 10 questions asked by the teachers, one question was recall, requiring students to retrieve factual information. On average every 20 questions asked, one was *direct comprehension check questions*, directly asking if students understood, and one was *vocabulary check questions*, asking directly if students knew certain vocabulary. The noticeable use of *vocabulary check questions* also corresponds with the findings about language focused episodes, presented in Section 4.1.10 Language focused episodes (LFEs) earlier, where vocabulary-focused LFEs were the main type and were often conducted through teachers' direct checks of whether the students understood them.

4.1.11.2.2) Frequency - Variation among lessons

Following the section above on the results of the 30 lessons as a whole, this section presents the number of different types of questions in each lesson.

a. The constructivist questions

Table 38 below lists the number of teacher questions in each lesson of the following questioning approaches: *pumping, association of key words and phrases, multi-pronged questioning* and *stimulating multimodal thinking,* as identified in Chin's (2007) framework. The rest of the questioning approaches in Chin's (2007) framework are not included because of the minimal presence they had and in most lessons these approaches were absent.

No.	lesson	pumping	constructive challenge	reflective toss	association of key words and phrases	verbal cloze	multi-pronged questioning	stimulating multimodal thinking	framing and zooming	question-based prelude	question-based outline	question-based summary
1	Edward 1st lesson	1	0	0	4	0	4	0	0	0	11	0
2	Edward 2nd lesson	0	0	0	0	0	0	0	0	0	0	0
3	Christina 1st lesson	11	0	0	0	0	0	4	0	0	0	0
4	Christina 2nd lesson	13	0	0	0	0	0	0	0	0	0	0
5	Chad 1st lesson	3	0	0	4	0	0	0	0	0	0	0
6	Chad 2nd lesson	7	0	0	13	0	0	0	0	0	0	0
7	Colin 1st lesson	4	0	0	5	0	0	0	0	0	0	0
8	Colin 2nd lesson	0	0	0	2	0	0	0	0	0	0	0
9	Emma 1st lesson	11	0	0	0	0	0	0	0	0	0	0
10	Emma 2nd lesson	6	3	0	0	0	0	0	0	0	0	0
11	George 1st lesson	20	0	0	111	1	0	17	0	0	0	0
12	George 2nd lesson	44	3	0	65	0	9	2	0	0	0	0
13	Hannah 1st lesson	11	1	0	1	0	6	4	0	0	0	0
14	Hannah 2nd lesson	14	0	0	3	0	7	0	0	0	0	0
15	Jenny 1st lesson	27	0	0	4	0	0	0	2	0	0	0
16	Jenny 2nd lesson	17	0	0	0	0	0	0	0	0	0	0
17	Johnson 1st lesson	18	3	0	0	0	0	0	0	0	0	0
18	Johnson 2nd lesson	9	0	0	0	0	3	4	10	0	0	0
19	Kate 1st lesson	11	0	0	0	0	0	0	0	0	0	0
20	Kate 2nd lesson	7	0	0	0	0	0	0	0	0	0	0
21	Mat 1st lesson	6	0	0	2	0	0	0	0	0	0	0
22	Mat 2nd lesson	6	0	0	0	0	0	0	0	0	0	0
23	Lennon 1st lesson	44	0	0	0	0	0	11	0	0	0	0
24	Lennon 2nd lesson	40	0	0	0	0	0	0	0	0	0	0
25	Louis 1st lesson	4	0	0	0	0	0	0	0	0	0	0

26	Louis 2nd lesson	13	0	0	0	0	0	0	0	0	0	0
27	Nicolas 1st lesson	11	0	0	0	0	0	0	0	0	0	0
28	Nicolas 2nd lesson	26	0	0	0	0	0	0	0	0	0	0
29	Stella 1st lesson	12	0	0	6	0	0	0	0	0	0	0
30	Stella 2nd lesson	19	0	0	0	0	0	2	0	0	0	0
	total	**415**	**10**	**0**	**220**	**1**	**29**	**44**	**12**	**0**	**11**	**0**
	average	**13.8**	**0.3**	**0.0**	**7.3**	**0.0**	**1.0**	**1.5**	**0.4**	**0.0**	**0.4**	**0.0**
	standard deviation	**11.9**	**0.9**	**0.0**	**22.9**	**0.2**	**2.4**	**3.7**	**1.8**	**0.0**	**2.0**	**0.0**

Table 38 the number of teacher questions of various constructivist questioning approaches in each lesson

As can be seen from Table 38 above, the use of *association of key words and phrases* has a rather drastic variation among the 30 lessons. George's two lessons contributed significantly to the overall number of questions used in this questioning approach while the use of it was consistently low in most of the other lessons. The examination of the variation provides the important information that, although, the sum of all the questions used in the 30 lessons has a noticeably high percentage of *association of key words & phrase*, i.e., 13.5%, this does not mean all the teachers used it frequently. In fact, apart from one teacher's particularly heavy use of it in his two lessons, most teachers never or barely used it.

Regarding the use of *pumping*, there was also a fairly obvious range of variation, however, with more consistency, across the 30 lessons. It can be seen that George's first lesson and Lennon's two lessons had a particularly high number of questions involved in episodes of *pumping*. Overall, almost all the lessons had a steady presence of *pumping*. However, *multi-pronged questioning* and *stimulating multimodal thinking* were mainly found in several lessons, such as George's first lesson and Lennon's first lesson for the use of *stimulating multimodal thinking*, and George's second lesson and Hannah's second lesson for the use of *multi-pronged questioning*. Another observation is multiple approaches were more frequently used in the same lessons. For example, two or three questioning approaches had an obvious stronger presence in George's two lessons, Hannah's two lessons, Jenny's first lesson, Lennon's first lesson etc. This suggests that some specific individual teachers exhibited a wider range of questioning strategies than others in the lessons observed. This could also be influenced by the topic or teaching activities in these lessons as there were no repetition of the same topics in the 30 lessons.

In summary, the variation of the constructivist questioning approaches reinforces the findings that most teachers had a rather narrow range of use of different constructivist questioning approaches and most of the constructivist questions were *pumping*.

b. The non-constructivist questions

Table 39 below shows the number of the non-constructivist types of teacher questions in each lesson.

No.	lesson	recall questions	direct comprehension check questions	vocab check questions
1	Edward 1st lesson	34	0	1
2	Edward 2nd lesson	0	0	0
3	Christina 1st lesson	14	0	3
4	Christina 2nd lesson	2	3	1
5	Chad 1st lesson	37	1	6
6	Chad 2nd lesson	0	0	0
7	Colin 1st lesson	0	0	29
8	Colin 2nd lesson	0	0	8
9	Emma 1st lesson	0	13	3
10	Emma 2nd lesson	1	3	0
11	George 1st lesson	11	0	0
12	George 2nd lesson	0	9	0
13	Hannah 1st lesson	3	3	6
14	Hannah 2nd lesson	0	0	1
15	Jenny 1st lesson	4	15	9
16	Jenny 2nd lesson	4	3	0
17	Johnson 1st lesson	0	0	0
18	Johnson 2nd lesson	0	0	0
19	Kate 1st lesson	0	1	0
20	Kate 2nd lesson	0	0	7
21	Mat 1st lesson	1	0	0
22	Mat 2nd lesson	7	0	2
23	Lennon 1st lesson	0	12	1
24	Lennon 2nd lesson	19	18	0
25	Louis 1st lesson	4	1	0
26	Louis 2nd lesson	0	0	0
27	Nicolas 1st lesson	8	2	0
28	Nicolas 2nd lesson	15	2	1
29	Stella 1st lesson	1	1	2
30	Stella 2nd lesson	0	2	6
	total	**165**	**89**	**86**
	average	**5.5**	**3.0**	**2.9**
	standard deviation	**9.6**	**5.0**	**5.7**

Table 39 the number of the non-constructivist types of teacher questions in each lesson

It can be seen that *recall* questions had a rather wide range of variation, with as many as 35 to 40 questions asked in Aaron's first lesson and Chris's first lesson and as few as zero to 10 questions in many other lessons. There was generally a small number of *vocabulary check questions* in

most lessons (e.g. between zero to 10 questions), aligning with the results of the overall use of them in 30 lessons shown in Section 4.b. The non-constructivist questions. However, the exception was Colin's first lesson where as many as 30 *vocabulary check questions* were asked, where a sizable proportion of the lesson time was spent on the teacher going through a list of key vocabulary items for the new chapter with the students. *Direct comprehension check questions* also had a minimal presence in most of the lessons, as the overall results of the 30 lessons show, but several lessons had a surge of them, e.g., Emma's first lesson, Jenny's first lesson, and Lennon's two lessons, where approximately 10 to 20 *direct comprehension check questions* were used, although there was no special use of instructional activities that could seem to explain this surge.

The variation of the three types of non-constructivist questions show that while they had a small presence in the 30 lessons overall, i.e., 20.9% of all questions asked, there were obvious variations across the 30 lessons. This indicates that individual teachers used these questions rather differently in their lessons.

4.1.11.2.3) Time length – results of the 30 lessons

While the results of frequency (i.e. the number of occurrences) provide an important parameter in measuring teachers' use of questions, another insightful aspect is the time length of the whole teacher-student exchange led by each questioning approach or type. This means the time length of the whole dialogue or IRF sequence initiated by these questions, including teacher questions, student responses, teacher feedback and possible wait time. Again, the unit of analysis here is individual dialogues. While the reason for considering the time length of the dialogue lies in the rational of the development of the constructivist questioning approaches explained in Chin's (2007) framework, as mentioned earlier in Section 3.5.3.11 in Chapter 3 Methodology, the time length of the dialogues where the three non-constructivist question types were situated were also calculated to provide comparisons and a full picture.

Table 40 below provides the results of the time length in the 30 lessons in total.

Question types	**Time length of the dialogue(in mins)**	**Time percentage to the total time length of dialogues**
Questions considered as constructivist (coded using Chin (2007)'s framework)	**742**	**76.9%**
Socratic questioning	243.4	59.2%
• pumping	239.3	52.8%
• Constructive challenge	4.1	1.0%
• Reflective toss	0	0.0%
Verbal jigsaw	39.6	9.6%
• association of key words and phrases	39.4	9.6%
• verbal cloze	0.2	0.0%
Semantic tapestry	27.9	6.8%
• multi-pronged questioning	10.6	2.6%
• stimulating multi-model thinking	11.4	2.8%
• framing and zooming	5.9	1.4%
Framing	5.2	1.3%
• Question-based prelude	0	0.0%
• Question-based outline	5.2	1.3%
• Question-based summary	0	0.0%
Questions considered as non-constructivist (developed inductively in this research)	**95.4**	**23.2%**
Recall	44.2	10.7%
Direct comprehension check questions	10.2	2.5%
Vocabulary check questions	41	10.0%

Table 40 the time length and percentage of the whole IRF sequences different types of teacher questions were situated within

Figure 20 below visualizes the percentages shown in Table 39 above.

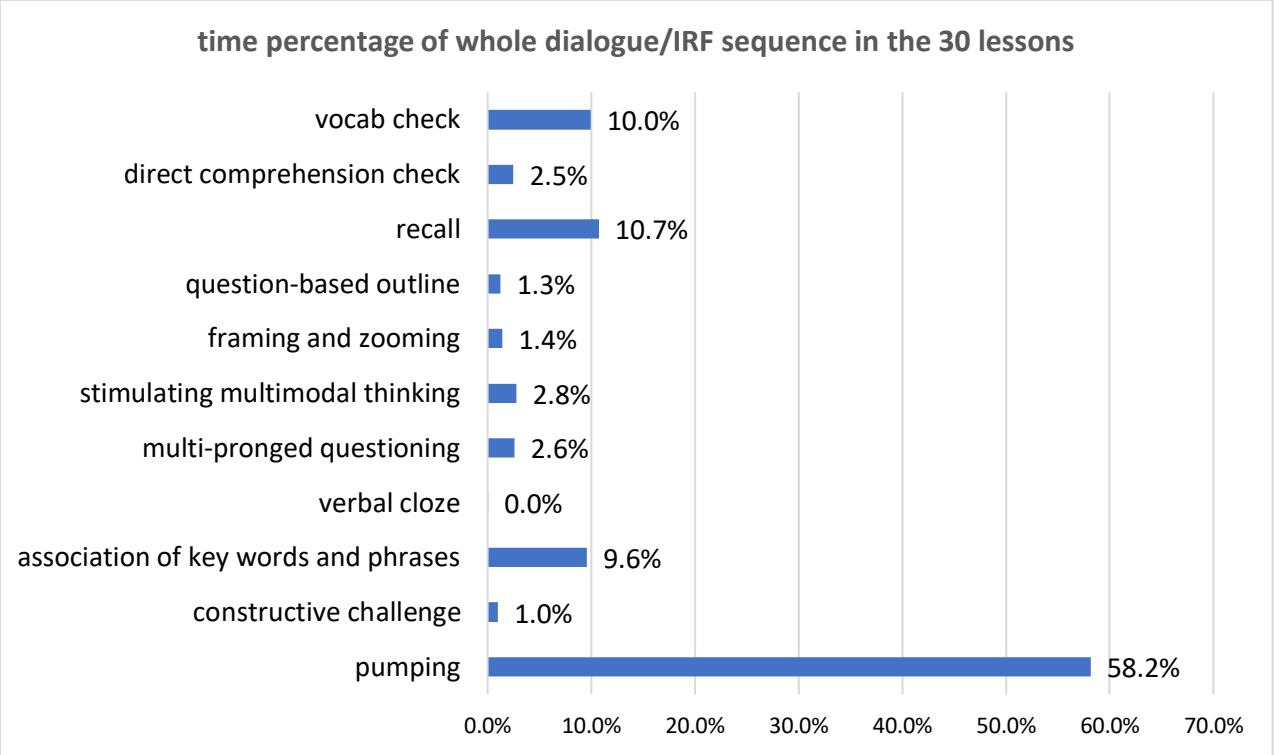


Figure 20 total IRF time length (in minutes) in 30 lessons of all T question types

Comparisons between the frequency and time length of all the question approaches and types in the 30 lessons in total show that most of the questioning approaches and types were consistent in these two measurements. This means the questioning approaches and types that involved a higher number of individual questions also led longer dialogues all together. For example, the dialogues *pumping* was involved in also took the longest time, i.e., 239.3 minutes, and the biggest percentage, i.e., 52.8%, in the 30 lessons. The questioning approaches that had a minimal number of individual questions also occupied much less time with the whole teacher-student exchange, e.g., the dialogues of *constructive challenge* only occupying 4.1 minutes in total in the 30 lessons.

A few cases do not follow this pattern of consistency. The most obvious differences lie in *pumping* and *association of key words and phrases*. *Pumping* took 25.6% of all the questions asked regarding frequency but took as much as 58.2% of the dialogue time. *Association of key words and phrases* occupied 13.5% regarding the number of questions asked, but only took 9.6% of the time of the dialogues all question types were situated within. A close look at the lesson transcripts shows that the dialogues aimed at reinforcing key technical vocabulary consumed less time because the students typically provided short answers of the target key technical vocabulary

the teacher question was aiming to reinforce, and when no response were provided, the teachers provided short feedback. In comparison, *pumping* questions in this research sometimes involved longer teacher questions, teachers' paraphrasing and breaking down of the original question in response to the failure of eliciting answers from the students, and more substantial teacher feedback, thus taking more time.

Despite the difference in how quickly the dialogues were conducted, *pumping* and *association of key words and phrases* were overall the two most prominent questioning approaches used in this research. *Pumping* was the most widely used questioning approach regarding both frequency and time lengths of IRFs, and *association of key words and phrases* were the second widely used approach regarding frequency and third regarding time length of IRFs.

4.1.11.3) Teachers' limited success of using pumping

Although *pumping* was commonly used across the 30 lessons and it is the questioning approach that aims to foster student talk (Chin, 2007), a close look at the transcripts shows that the actual student output elicited was often still rather limited. Often the students only produced certain key words and did not provide a full and clear explanation of their thoughts. Instead, the teachers in the end were frequently observed to provide the full answer themselves, as also pointed out in Section 4.1.8 earlier on the ration of noun and verb in student talk. An example from Mat's second Biology lesson, shown below in Excerpt 25, provides a clear illustration.

Excerpt 25

Turn	Timespan	Content	Speaker	Teacher questions
34	19:03.0 - 19:06.0	Debbie, do you think identical twins have the same fingerprints?	T	pumping
35	19:06.0 - 19:07.0	No.	Debbie	pumping
36	19:07.0 - 19:08.0	Why?	T	pumping
37	19:08.0 - 19:11.0	Eh… because it's just…no.	Debbie	pumping

38	19:11.0 - 19:27.0	Just no. Well yeah, alright, they don't. Fingerprints are not genetic. You don't get your thumbprints or your fingerprints from your genes. Fingerprints actually arrive when you're growing inside the womb and it's just your skin folding randomly.	T	pumping

As Turn 37 shows, the student seemed to have difficulties in explaining her thoughts on whether identical twins have the same fingerprints. The teacher, in Turn 38, immediately provided a full and detailed explanation himself. This example demonstrates the typical situation where teachers' use of *pumping* faced limited success in eliciting students' full explanations of their thoughts, as the approach *pumping* aims to do (Chin, 2007) and the teachers frequent act of providing the full explanation themselves. Another example, shown in Excerpt 26 below, which is also given in Appendix 15, also demonstrates the common situation of the limited success of *pumping* in this research. This excerpt is from Christina's second Biology lesson on sea floor spreading.

Excerpt 26

Turn	Timespan	Content	Speaker	Teacher questions
11	2:03.0 - 2:17.0	So, um the strip in purple indicates normal magnetic polarity. What does that mean? Normal magnetic polarity?	T	pumping
12	2:17.0 - 2:20.0	[wait time]		pumping
13	2:20.0 - 2:21.0	Normal,	T	pumping
14	2:21.0 - 2:25.0	[wait time]		pumping
15	2:25.0 - 2:26.0	What do you think?	T	pumping
16	2:26.0 - 2:27.0	[Wait time]		pumping
17	2:27.0 - 2:39.0	So, if we are talking here the magnetic field of the earth, ok, and this here [T pointing at the rock on the PPT slide] has hardened, it has recorded the what?	T	pumping
18	2:39.0 - 2:43.0	[wait time]		pumping

19	2:43.0 - 2:52.0	Now the urgh that the magnetic field of the earth [T using gestures to show “the strip”] the same as now, if it's normal?	T	pumping
20	2:52.0 - 2:54.0	[wait time]		pumping
21	2:54.0 - 3:24.0	Hum it's not really difficult. Anyways, so with this [audible] saying [T pointing at the ridge on PPT], when the rock had hardened, um, it recorded the earth magnetic field at its normal state.	T	pumping

This whole excerpt of *pumping* took 1 minutes 21 seconds. Unlike the limited answer the students were able to provide Excerpt 25 earlier, the students in this case did not provide any answers to the teacher’s question on normal magnetic polarity and the subsequent paraphrased questions. The teacher asked the question again by restating the key word, ‘*normal*’, in Turn 13, and asked again ‘*what do you think*’ in Turn 15. These two attempts were also coded as ‘R’ for repetition and reformulation of a previous question, as explained earlier in Section 4.1.9.3. Then, in Turns 17 and 19, the teacher proceeded with giving away more hints and asked the question in a different way with the use of the visual on the PPT slide. Eventually the teacher gave up in Turn 21 by saying this was not really difficult and provided the correct answer herself, which is that the rock recorded the earth’s magnetic field at its normal state. This example also demonstrates the situations where no responses from the students were elicited and the teacher had to provide hints and asked further questions to break down the original question in the use of *pumping.* This limited success of *pumping* also corresponds with teachers’ frequent use of repetition and reformulation of questions, the short student turn length and the limited linguistic complexity in student talk indicated by a high noun-verb ratio, presented earlier.

4.1.12 Student questions

After examining teacher questions in the sections above, student questions is also a crucial area to investigate. In this section, results about all student questions will be given first, followed by results on the different types of student questions.

4.1.12.1) All student questions

On average there were only 2.4 student initiations, i.e., student questions, in a lesson and each student question was as short as 2.3 seconds, occupying only 0.6% of the interaction time.

The quantitative results of student questions in each lesson is shown in Table 41 below, with averages shown at the bottom of the table.

no.	lessons	number of occurrences	overall length (secs)	average length per S-I (secs)	percentage of the interaction time
1	Edward 1st lesson	1	4.0	4	0.2%
2	Edward 2nd lesson	0	0.0	0	0.0%
3	Christina 1st lesson	5	8.0	1.6	0.5%
4	Christina 2nd lesson	2	2.0	1	0.2%
5	Chad 1st lesson	0	0.0	0	0.0%
6	Chad 2nd lesson	0	0.0	0	0.0%
7	Colin 1st lesson	0	0.0	0	0.0%
8	Colin 2nd lesson	0	0.0	0	0.0%
9	Emma 1st lesson	0	0.0	0	0.0%
10	Emma 2nd lesson	0	0.0	0	0.0%
11	George 1st lesson	4	7.4	1.9	0.4%
12	George 2nd lesson	3	17.4	5.8	0.8%
13	Hannah 1st lesson	5	17.0	3.4	0.9%
14	Hannah 2nd lesson	0	0.0	0	0.0%
15	Jenny 1st lesson	5	6.0	1.2	0.3%
16	Jenny 2nd lesson	2	3.8	1.9	0.6%
17	Johnson 1st lesson	0	0.0	0	0.0%
18	Johnson 2nd lesson	0	0.0	0	0.0%
19	Kate 1st lesson	0	0.0	0	0.0%
20	Kate 2nd lesson	1	6.0	6	0.3%
21	Mat 1st lesson	1	1.0	1	0.1%
22	Mat 2nd lesson	0	6.0	0	0.3%
23	Lennon 1st lesson	2	3.7	1.8	0.2%
24	Lennon 2nd lesson	4	10.6	2.6	0.4%
25	Louis 1st lesson	1	5.0	5.0	0.2%
26	Louis 2nd lesson	4	28.0	7.0	2.3%
27	Nicolas 1st lesson	3	26.4	8.8	1.7%
28	Nicolas 2nd lesson	4	9.9	2.5	0.8%
29	Stella 1st lesson	10	63.6	6.4	3.0%

30	Stella 2nd lesson	14	96.2	6.9	5.1%
	total	**72**	**321**		
	average	**2.4**	**10.7**	**2.3**	**0.6%**
	standard deviation	**3.2**	**20.4**	**2.6**	**1.1%**

Table 41 student questions in each lesson

As can be seen from Table 40 above, the number of occurrences of student questions remained low in most of the lessons, with Stella's lessons as an outlier. Similarly, most lessons had a minimal time percentage of S-Is in the interaction time, except only a few lessons, namely, Louis's second lesson (2.3%), Stella's first lesson (3.0%) and Stella's second lesson (5.1%). Overall, the results show that the students seldom asked questions and when they did, the questions were also rather short, which potentially indicates limited complexity of linguistic structure in their questions.

4.1.12.2) *Different types of student questions*

After examining the number of occurrences and average time length of student questions, it is also important to investigate the content of them. The elaboration of the coding framework of student questions are given in Chapter 3 Methodology. Similar to the coding framework of teacher questions, the coding framework of student questions did not cover all the student questions in the lessons and some questions could not be coded using the coding framework.

4.1.12.2.1) Overall pattern

The frequency percentage of different types of student questions in the 30 lessons in total is shown in Figure 21 below.

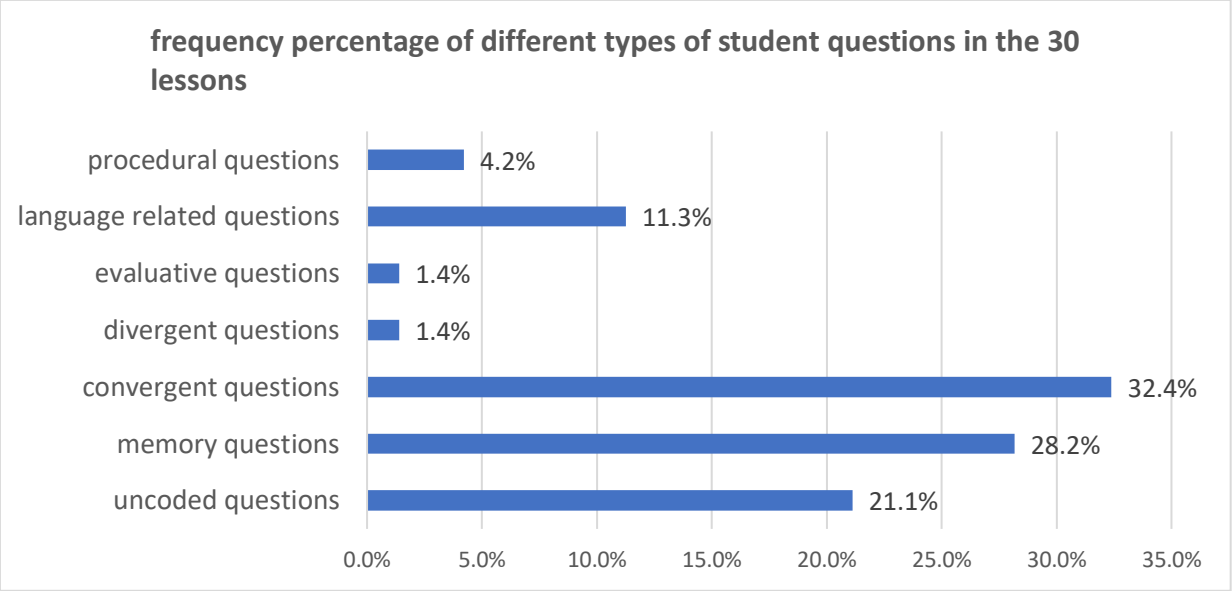


Figure 21 frequency percentage of different types of student questions in the 30 lessons

As can be seen, among all the 71 student questions across the 30 lessons the majority of student questions were *memory questions*, taking up 28.2% of all the student questions, and *convergent thinking questions*, taking 32.4%, while *divergent thinking questions* and *evaluative thinking questions* were almost non-existent across the 30 lessons. This means most often the students asked about factual information or analysis and integration of given information that leads to a correct answer. The students rarely raised questions that involve creating new ideas or making judgement. In fact, there was only one *divergent thinking question* and *one evaluative thinking question*. This is, to an extent, unsurprising as *divergent thinking* and *evaluative thinking questions* are of a higher level of cognitive thinking (Gallagher & Aschner, 1963).

There was also a very small number of *language-related questions*, i.e., 8, occupying 11.3% of all the student questions. *Procedural questions* also took a very small percentage, as low as 4.2%. This indicates that overall students did not raise concerns about language much or enquired about the procedures of administering science tasks. 21% of the total student questions, i.e., 15 questions, are uncoded, which means these student questions do not fall into any type of the student questions as mentioned above.

Examples of all the types of student questions are given in Appendix 17 and Appendix 18, and are not repeated here.

4.1.12.2.2) Variation

To examine how the overall number of questions distributed across the lesson sample, this section breaks down the results mentioned above to examine whether there is much variation across the 30 lessons. Table 42 below shows the number of different types of student questions in each lesson.

no.	lessons	memory	convergent	divergent	evaluative	language related	procedural
1	Edward 1st lesson	1	0	0	0	0	0
2	Edward 2nd lesson	0	0	0	0	0	0
3	Christina 1st lesson	2	3	0	0	0	0
4	Christina 2ndlesson	0	0	0	0	0	0
5	Chad 1st lesson	0	0	0	0	0	0
6	Chad 2nd lesson	1	0	0	0	2	0
7	Colin 1st lesson	0	0	0	0	0	0
8	Colin 2nd lesson	0	0	0	0	0	0
9	Emma 1st lesson	0	0	0	0	0	0
10	Emma 2nd lesson	0	0	0	0	0	0
11	George 1st lesson	2	1	0	0	0	0
12	George 2nd lesson	2	0	0	0	1	0
13	Hannah 1st lesson	1	3	0	0	0	0
14	Hannah 2nd lesson	0	0	0	0	0	0
15	Jenny 1st lesson	0	0	0	0	0	0
16	Jenny 2nd lesson	0	1	0	0	0	0
17	Johnson 1st lesson	0	0	0	0	0	0
18	Johnson 2nd lesson	0	0	0	0	0	0
19	Kate 1st lesson	0	0	0	0	0	0
20	Kate 2nd lesson	0	0	0	0	0	1
21	Mat 1st lesson	0	0	0	0	1	0
22	Mat 2nd lesson	0	2	0	0	0	0
23	Lennon 1st lesson	1	0	0	0	0	0
24	Lennon 2nd lesson	2	2	0	0	0	0
25	Louis 1st lesson	0	1	0	0	0	0
26	Louis 2nd lesson	0	3	0	0	0	1
27	Nicolas 1st lesson	0	0	1	1	0	1
28	Nicolas 2nd lesson	3	1	0	0	1	0
29	Stella 1st lesson	0	1	0	0	1	0

30	Stella 2nd lesson	5	5	0	0	2	0
	total	**20**	**23**	**1**	**1**	**8**	**3**
	average	**0.7**	**0.8**	**0.0**	**0.0**	**0.3**	**0.1**
	standard deviation	**1.2**	**1.3**	**0.2**	**0.2**	**0.6**	**0.3**

Table 42 the number of different types of student questions in each lesson

As Table 42 shows, the students in certain classes asked more *convergent thinking questions* than others, with several having a small surge of *convergent questions*, e.g. Stella's second lesson having five, and Christina's first lesson, Hannah's first lesson and Louis's second lesson each having three *convergent thinking questions*. On the other hand, many lessons did not have any *convergent thinking questions* at all. This means although overall *convergent thinking questions* were the most frequently asked (i.e., 23 of them in the 30 lessons), this does not represent the general situation in all lessons but is rather the result of a small number of lessons contributing significantly to this overall high number.

Regarding the second mostly frequently asked type of questions, *memory questions*, there was a rather even distribution of them across the 30 lessons with quite a few lessons having one or two *memory questions* asked by students. However, in Stella's second lesson, students asked obviously more memory questions, i.e., five. As for the eight language-related questions, they were also evenly spread out with one or two of them asked in several individual lessons, without a particular high concentration of them in individual lessons. The higher-order thinking questions, i.e., *divergent and evaluative questions*, only took place once each and both in Nicolas's first Biology lesson. As these questions took place so rarely but are of significant value for advancing science learning, the lesson excerpts of these two questions are examined below in Section 4.1.12.3.

All in all, the findings above suggest that the students in this study were most comfortable with asking about factual information that requires recall of knowledge. The students in several individual classes also demonstrated their ability of asking *convergent questions* which enquired about reasons, functions, and relationships among concepts which usually have fixed correct answers. There was an absence of *divergent thinking* and *evaluative thinking questions* in almost all of the 30 lessons, which indicates students' difficulties in organising or delivering the

questions that require a higher level of cognitive activities, such as predicting, inferring, hypothesizing, reconstructing, valuing, judging and so on. Only a small number of students voluntarily asked about certain language features or showed communication breakdown through their questioning. This means there was still a low tendency for students to actively enquire about the English language in these EMI science lessons.

4.1.12.3) The context of higher-level thinking student questions

As explained earlier, higher-level thinking questions were very rare in the 30 lessons. However, the only *divergent thinking question* and *evaluative thinking question* both took place in the same lesson, Nicolas's first Biology lesson, where a class debate was held between the boys and girls on whether stem cell should be allowed. Because of the significant value of higher-order thinking questions for students' science learning, the two excerpts of lessons where these two questions took place are shown below, in Excerpt 27 and Excerpt 28.

Divergent questions:

Excerpt 27

Turn	Timespan	Content	Speaker	Ss Questions
50	11:32.2 - 11:52.0	I er I have a question. If we choose to do the research, and we finally, we get a disease maybe in the future, err, but can we, if we found it, can do cure it by the [pause 2 secs]	S	divergent
51	11:51.9 - 11:53.9	If you do this research, can you cure it once you find it?	T	
52	11:53.8 - 11:54.9	Yeah.	S	
53	11:54.9 - 12:36.2	That's what they don't know. Because they haven't done enough research with it, because it's banned to be able to, for tell, hey, if we did this, we are now able to cure X, Y and Z, whatever the disease it is. So, because they are not even allowed to do it, this is still part of the debate. Because you have Richard's point of don't even start it because it's Pandora's box. You are opening something you don't know - what consequences can come out of it? And you are saying [T looking at the girls], just let us do it, and we can choose whether we want to use it or not. But by being limited to the fact that you can't even mess with it, still you still have the debate of what if, what's going on, I don't know.	T	

Evaluative questions:

Excerpt 28

Turn	Timespan	Content	Speaker	Ss Questions
38	8:00.6 - 8:02.4	*So, you are prolonging the human species, but you are potentially threatening all the other species,	T	
39	8:08.2 - 8:19.3	Yeah, do you like this consequences? Just, you know, remaining all human beings will kill all other things out, err, err, die out.	S	evaluative

Both the *divergent* and *evaluative questions* were directed at the opposition team (i.e., either the boy's team or the girls' team) rather than the teacher. There were no *divergent* and *evaluative thinking questions* in ordinary teacher-centred situation where student questions were raised to the teachers and teachers were expected to answer them. This shows the particular context of the occurrence of the higher-level questions in this research. Students' asking the *divergent* and *evaluative thinking questions* seems to be because of the setting of the class debate activity and possibly the theme of the debate (i.e. whether stem cell research should be allowed). It could be speculated that more cognitive space was created for students to make judgements, predictions, evaluations and so on through questioning each other. This shows the higher-order thinking student questions in this study were limited to one type of class activity and the traditional teacher-centred student-teacher dialogues may not be as effective in encouraging the use of these questions. More elaboration is given in Chapter 7 Discussion and Conclusion.

Another interesting issue *the divergent question* excerpt brings up is that it seems there is some ambiguity regarding what exactly the student's question meant and what the teacher understood, and whether this might be caused by the language issue. The student who spoke in Turn 50 seems to ask if stem research is permitted and a cure is found to some disease, whether this cure can used. However, the teacher's paraphrase in Turn 51 is a bit ambiguous as it could mean whether the cure is effective, or whether the cure is allowed to be used, although in the end in Turn 53 the teacher gave a more detailed explanation. The use of the language in Turn 53 by the teacher may cause some ambiguity in clearly expressing what he understood about the student's previous question, and potentially making it difficult for the student to judge whether the teacher understood him correctly. This conversation demonstrates that in the EMI science classes the

difficulty with the use of English may cause issues with accuracy in expression and comprehension when a higher-level thinking question is asked.

4.1.12.4) The language difficulty

Apart from analysing the different types of questions students asked, a pattern that emerged with the student questions is the language issue the students faced in phrasing their questions clearly in L2 only and the process of negotiation and meaning that often followed for the teacher to understand the students' questions. It is often observed that negotiation of meaning took place for several IRF cycles between the student and the teacher to clarify the exact meaning of the student's question.

The Excerpt 29 below from Stella's first Biology lesson on the structure of plants demonstrates the lengthy negotiation of meaning process where a student raised a question on '*epidermis*', a new concept introduced in that lesson.

Excerpt 29

Turn	Timespan	Content	Speaker	IRF
5	1:27.9 - 1:39.2	Err, Ms Steele, the epidermis are all the covers of a leaf ...or just one type, err, just this certain type?	S1	S-I (1)
6	1:39.2 - 1:41.2	What do you mean by covers?	T	T-R (1)
7	1:41.2 - 1:44.8	Err, the cover of.	S1	S-R (1)
8	1:44.7 - 1:50.3	*Oh! The epidermis covers the leaf surface [T pointing to the drawing]	T	T-R (2)
9	1:50.3 - 1:55.3	Yeah, it could have many features, but they are all called epidermis?	S1	S-R (2) & S-I (3)
10	1:55.3 - 2:08.3	Yes, so if you have a sticky leaf, that's still an epidermis that's causing, that's covering the leaf. If you have a hairy leaf, that's still an epidermis covering the leaf surface.	T	T-R (3)
11	2:08.3 - 2:14.9	So, it doesn't have a special name for different kinds of?	S1	S-I (4)

12	2:14.9 - 2:27.8	*Not that I know of. There might be on the textbook but now each leaf has a different name. Because depending on the plant, they have different shapes, and different sizes of leaves.	T	T-R (4)
13	2:27.8 - 2:28.7	Yeah, ok.	S1	S-R (4)

In Excerpt 29 above, the student asked a question in Turn 5 to ask for clarification of the new concept, epidermis. However, the teacher did not seem to understand fully the student's question and asked back the student '*what do you mean by covers?*', indicating communication breakdown and initiating negotiation of meaning. In Turn 7, the student was trying to modify his original question but was cut off by the teacher before she was able to produce a complete sentence – '*Er, the cover of*'. In Turn 8, the teacher provided her own interpretation and in Turn 9 the student confirmed and was able to provide a complete modification of her original question – '*yeah, it could have many features, but they are all called epidermis?*'. Eventually in Turn 10, the teacher understood the student's question accurately, and the communication breakdown was resolved. From the student's original question until the teacher provided her explanation, there were three IRF cycles with an incidence of negotiation of meaning where the teacher issued back a clarification request and the student modified her original question twice in Turn 7 and Turn 9. This excerpt shows the difficulty for the students to put across their questions about science ideas to their teacher in L2. However, this is not to say that in L1 science classes the students do not need to modify their questions, but in EMI science classes the process for a student to ask questions and for the teachers to provide the explanation asked for may be lengthier and involve more IRF cycles.

Another observation made about this excerpt is that when the student tried to modify her question in Turn 7 and Turn 12, the teacher did not wait until she finished her question but cut her off and provided her answer based on her interpretation. It could be argued that in EMI classes because of the language difficulty, students need more time to process the science ideas and phrase their questions in an L2, which is also beneficial for their L2 learning. More elaboration will be provided in Chapter 7 Discussion and Conclusion.

4.2 Summary of the chapter

Classroom interaction is a complex and dynamic process. To understand it accurately would require examination of multiple aspects of it. The results of the 12 parameters provide evidence of various aspects of classroom interaction which have been argued to be of pedagogical significance in the literature, as explained in Chapter 3 Methodology. A brief summary is provided here to make initial linkage among these 12 dimensions. A more detailed and comprehensive narrative is provided in Chapter 7 Discussion and Conclusion.

Overall in the 30 lessons teacher talk took a dominant role with limited student output in terms of both quantity and quality. This difficulty of eliciting output from the students is reflected in several aspects, including the teachers' frequent use of reformulation and repetition of questions, the teacher's limited success with the use of *pumping*, and the no response often received after teacher nominations. Wait time after teacher initiations and student responses was also generally low despite teachers' fairly heavy use of constructivist questions and the challenge that the students faced to comprehend the questions and produce answers in an L2. The combination of the short wait time and the frequent use of constructivist questions, which requires higher-order thinking from students, may also have contributed to students' limited output and their fragmented answers featuring single key words and phrases rather than complete sentences.

Certain effort from the monolingual teachers in promoting classroom interaction was observed. This include frequent use of teacher questions and the high proportion of one type of constructivist questions, i.e., *pumping*, short individual monologues in many lessons, and again the frequent use of reformulations and repetitions of a previous question as a gesture of persisting on eliciting students' responses. However, results of other parameters reflected certain less favourable behaviour in promoting teacher-student interaction to facilitate science and language learning. For example, despite being generally short, the teacher monologues were used rather frequently. Teacher nomination was scarcely used in most lessons and the teachers predominantly used *pumping* as the main way to promote productive thinking with a lack of a variety of constructivist questioning approaches. It was

also often observed that the teachers did not require or scaffold the students to produce complete sentences and instead they often accepted students' fragmented answers featuring a key word and provided full answers themselves. While the students were asking questions themselves, sometimes the teachers were observed to have cut them off rather than waiting. With the additional difficulty L2 poses, the teachers only used group discussion to a limited degree where the students could ask for clarifications from each other, develop understandings among themselves and rehearse answers in L2. Moreover, language-focused episodes (LFEs) were also rather limited in most lessons, with a predominant focus on the meaning of vocabulary items, especially the non-technical ones. Overall, group discussion, LFEs, and wait time, which could have played a role in alleviating the language difficulty the students faced, was not made sufficient use of in the lessons.

Possible explanations of the classroom interaction pattern reported in this chapter could be found in the teachers' and students' beliefs about effective science and English learning in EMI science classes in Chapter 5 and Chapter 6. Teachers' and students' direct explanations of challenges they faced in classroom interaction are also given there. Connections between beliefs and practice will be made in Chapter 7 Discussion and Conclusion .

Chapter 5 Results of Teachers' Background and Beliefs about Teaching Science through English

This chapter presents the findings of the monolingual science teachers' professional background and their beliefs about teaching science and English in EMI science classes, addressing the following research question:

Research Question 2: What are foreign monolingual science teachers' professional background and their beliefs about teaching science to Chinese students through English only, particularly about the role of interaction?

Findings from the teacher background questionnaire will be presented first. Then, results from the teacher beliefs questionnaire will be shown, followed by findings from the teacher interviews.

5.1 Teachers' professional background

As the teachers' background questionnaires and the lesson observations show, all of the 15 teachers are foreign teachers who do not have a functioning level of Mandarin to use in their teaching. All of them wrote 'English' as their most proficient language in their background questionnaire, rated 'low' for their Mandarin proficiency and selected 'no' for whether they are able to use Mandarin in teaching in the teacher background questionnaire. This ensures all of the teachers fit the criteria of the target teacher population in this study, i.e., foreign monolingual teachers who are highly proficient in English and cannot switch to Mandarin in their teaching.

The details of each teacher's background are shown in Table 43 below. In the last column, 'language background', as all teachers had the same answers to the questions of 'most proficient language', 'level of Mandarin', 'able to use Mandarin to teach', as explained above, the answers to these questions are not included in this table.

teacher		past teaching experience			qualification			language background	
Sch	**Name (age, gender)**	**in China**	**English L1 contexts**	**English L2 students outside of China**	**Degree**	**Training in TESOL**	**Training in EMI**	**L1**	**Other languages you have learnt**
Sch 1	1.Emma (33, F)	1 year Chemistry Grade 11	4 years Science, Biology, Maths, English, French, senior secondary school in Canada	none	Bachelor of Science in Biology & Environmental studies and 1 extra year of Bachelor of Education in Secondary science and environmental education	none	none	Eng	French, medium
	2.Colin (54, M)	4 years ESL, Physics, Calculus, Math, Science, English, senior secondary school	15 years Math Science subjects Art, etc., senior secondary school in Canada (including first nation students)	5 years ESL Primary school in Korea; 9 years of teaching science subjects to first nation students in senior secondary schools in Canada	Bachelor of Science, minor English and 1 extra year of BEd K-12 Math and Science; 2 years RTR Diagnostic Imaging	none	none	Eng	French, low

	3.Kate (52, F)	2 years Maths, Science, Studio Arts, senior secondary school; Visual Arts, senior and junior secondary school	18 years all subjects except senior Maths, all grades K-12 in Canada (but more than 60% of the student having immigrant and first nations background)	2 years EFL conversation in Japan, children to adults	Bachelor of Arts in Theatre and History and 1 extra year Teacher training multicultural teacher education program (K-7 all subjects; teaching theory, psychology, Sociology)	16 days workshops on ESL	none	Eng	Japanese, French, Spanish, Slovak, Low
School	**Name (age, gender)**	**in China**	**English L1 students**	**English L2 students outside of China**	**Degree**	**Training in TESOL**	**Training in EMI**	**L1**	**Other languages you have learnt**
Sch 2	4.George (29, M)	1 year Biology, senior secondary school	2 years Chemistry, senior secondary school in Thailand	none	Bachelor of Science in Biology, Msc Pharm.Chemistry, MBA	TESOL 6 months	none	Eng	French, high

Sch 3	5.Lennon (25, M)	6 months Physics & Maths, Grade 12	2.25 years all subjects, French and Computers in Canada	none	Bachelor of Arts in Economics & 1 extra year of Bachelor of Education(Primary/Junior)	TEFL master course - 150 hours	none	Cantonese	French, high; Spanish low
	6.Louis (59, M)	1 year science subjects, senior secondary school	15 years science subjects secondary school in Canada	none	Bachelor of Education in sciences, Canada	none	none	Eng	Spanish, low
	7.Stella (24, F)	4 months Biology & Social studies& Language Arts, senior secondary school	none	1 year all subjects Grade 6 Canada to Inktihut Children; 3 weeks TESOL Grade 5 &Adults in Ecuador	Bachelor of Arts in History & English and 1 extra year for Bachelor of Education in primary (Kindergarten to Grade 6)	TESL/TEFL online course - 150 hours	none	Eng	noun
School	**Name (age, gender)**	**in China**	**English L1 students**	**English L2 students outside of China**	**Degree**	**Training in TESOL**	**Training in EMI**	**L1**	**Other languages you have learnt**
Sch 4	8.Chris (56, M)	1 year Science, Math, Music, Grade 10	7 years Chemistry, Physics, Biology, Math, secondary school in Canada	23 years ESL, Business English K-12 in Japan	Bachelor of Science in Biochemistry,2 years of Bachelor of Education in Science	none	none	Eng	Japanese, high; French, high

Sch 5	9.Nicolas (34, M)	1 year Chemistry and Biology, Grade 10 and 11	7 years Biology and Anatomy, secondary school in US	none	Bachelor of Science pre-medicine, Master of Science in teaching	TEFL certification, 16 weeks	none	Eng	Spanish, medium, Italian, low
Sch 6	10.Aaron (36, M)	4 years of Chemistry, Biology, Grade 11 and 12	none	1 year Maths, Chemistry, Biology secondary school in an IB international school in the US to foreign students	Bachelor of Science (Biochemistry)	none	none	Eng	Latin, low; Italian, low
School	**Name (age, gender)**	**in China**	**English L1 students**	**English L2 students outside of China**	**Degree**	**Training in TESOL**	**Training in EMI**	**L1**	**Other languages you have learnt**
Sch 7	11.Johnson (24, M)	3 years of Calculus, Physics, Grade 11 and 12	12 weeks Maths and Science, junior secondary school in Canada	none	Bachelor of Science in Geophysics and one extra year of Bachelor of Education in Secondary Maths and Science	One semester ESL in Secondary Education in Canada	none	Vietnamese	Vietnamese, medium

	12.Jenny (28, F)	4 years Chemistry, Biology and Maths, senior secondary school	none	none	Bachelor of natural science in Chemistry and 1 extra year for Bachelor of Education in Math/Science	English language learner course as part of the bachelor degree	none	Cantonese	Vietnamese, low
	13.Christina (31, F)	4 years Science, Social studies, Drama, ESL etc., Grade 10	none	13 weeks English, Math, Social Studies, Home economics, PE, Grade 6 to students with immigrant background in Canada; 6 months Language Arts, Social studies, Dance, Music, Grade 6&7 in Korea	Bachelor of Arts in Visual arts and 2 years of Bachelor of Education (middle years)	none	none	Tagalog	German, low
	14.Hannah (29, F)	5 years Science, Biology, Chemistry, senior secondary school	none	none	Bachelor of Science in Biology and 1 extra year for Bachelor of Education, Master's in education (in progress)	none	none	Punjabi	French, medium

	15.Mat (32, M)	2 years Biology, Physics, Chemistry, Senior Secondary school	2 years Biology, Physics, Chemistry, secondary school in Scotland	3 years Biology, Physics, Chemistry, secondary school in UAE	Bachelor of Science in Microbiology and PGDE in Biology and Science	none	none	Eng	none

Table 43 teachers' background

5.1.1 Age group and gender

As Table 43 above shows, there were six female teachers and nine male teachers. Most of the teachers were at their 20s or early 30s and the rest were at their 50s. A look at their answers as to why they came to teach in foreign high schools in China in the teachers' background questionnaire reveals that the difficulties of finding a full-time job back home and an interest in exploring a different culture are common motivations. The teachers in their 20s often mentioned the benefit in developing a few years of teaching experience of the curriculum that is taught in their home country before they can secure a full-time job back home.

5.1.2 Academic qualifications in science

All of the 15 teachers have a bachelor's degree. Four of them, although teaching a science subject at the high school level, did not have an academic degree in Sciences or training specifically in Sciences.

Kate, who was teaching Grade 10 Biology in a Canadian British Columbian program, has a bachelor's degree of Arts in Theatre and History and one extra year of multicultural teacher education program. Lennon, who was teaching Grade 11 Physics in a British Columbian program, has a Bachelor of Arts in Economics and one extra year of training in Bachelor of Education (Primary/Junior). Similarly, Stella, despite teaching Grade 10 Biology in a British Columbian program, holds a Bachelor of Arts in History & English with one extra year for a Bachelor of Education in Primary (K-6). Christina, teaching Grade 10 Biology in a British Columbian program, too, gained her Bachelor's in Arts in Visual arts, with two extra years for a Bachelor of Education (middle years). All these four teachers also reported little past teaching experiences in Science subjects, particularly at the high school level.

These four teachers without an academic degree in Sciences are from three different schools. This suggests that this finding may not be a special case for one school and may reflect a phenomenon among the foreign science teachers hired in foreign high school programs in China. Given the often demanding and sophisticated level of subject content in high school curricula,

this lack of academic qualifications may be a concern for students' science learning. This finding also raises questions regarding on what grounds the teachers were hired.

5.1.3 Academic qualifications related to language teaching and EMI

Apart from academic qualifications in teaching science, training in teaching languages is another area of interest in this study, considering the underlying dual goals of EMI classes. It can be seen from Table 43 above that seven teachers either had TEFL training as a component of their bachelor's degree or took TEFL or TESOL courses for a variety of time lengths, from as short as 16 days to as long as a few months. Regarding training in EMI, i.e., teaching non-language subject matters to non-native English speaking students, none of the 15 teachers had any.

5.1.4 Past teaching experience (in China, other L2 contexts, and L1 contexts)

All the 15 teachers had less than five years of teaching experience in China, ranging from only six months to five years. Nine had less than two years of teaching in China. Among the limited teaching experience in China, most of them taught science subjects in China and some also taught other subjects, like Maths, ESL, Social Studies etc. This shows that most of the 15 teachers in this study are relatively new to EMI in China and they are not strictly assigned to teach only science subjects. The short time span of their teaching experience also in a way reinforces the observation that EMI foreign high school programs is a relatively new phenomenon in China.

Regarding teachers' past teaching experience in L2 contexts other than China, where students also speak English as their L2, seven teachers had no experience and a few teachers reported less than five years of experience, mainly teaching ESL/EFL rather than subject knowledge. These L2 contexts include Japan, Korea, Thailand and UAE. A small number of teachers also reported having taught classes of first-nation students or foreign students in Canada or the US. Chris, as a rather special case, taught ESL for as long as 23 years in Japan before teaching science in China. Only a few actually taught science subjects in other L2 contexts (e.g., George having taught

Chemistry science in Thailand for two years and Mat having taught science subjects in UAE for three years). Overall, regarding teaching subject matter through English in L2 contexts outside of China, the teachers also had rather limited past experience.

As 11 teachers in this study are from Canada and immersion education has had a long history there (Cammarata & Haley, 2017), these teachers were also specifically enquired if they had taught in immersion programs, which share certain pedagogical similarities with the EMI contexts where teachers are also using students' L2 to teach subject matter. None of these teachers had immersion teaching experience, either. Together with the findings above, the teachers in this study only had limited experiences of using the students' L2 as the medium of instruction to teach subject content knowledge.

The last component enquired is teaching experience in L1 contexts where students speak English as their L1. There is a large range of years of past teaching experience in L1 contexts, from none to 18 years. While 11 teachers had less than five years and six had none, four had extensive teaching experiences, such as 7, 15 and 18 years. This shows that the majority of the teachers in this study are relatively inexperienced and a small number of them, who are at their 50s, are very experienced teachers. Most of them have mainly taught science subjects and only a few teachers have taught others such as Computer, Maths, Arts and languages. This shows that most of the 15 teachers also have limited past teaching experiences in L1 contexts. However, compared to the L2 contexts, they have more experience in the L1 contexts.

In summary, the overall picture of the 15 teachers' past teaching experience features limited experience with EMI in China or in other L2 contexts and more experience in ESL/EFL, either in China and other L2 contexts or in their home country with classes having ESL students.

5.1.5 Language background

As briefly specified earlier, all teachers have selected English as their most proficient language, and all chose 'low' to describe their Mandarin proficiency level. All of them also selected 'no' in whether they are able to use Mandarin to teach. Five teachers have had a non-English L1, such as Cantonese, Vietnamese, Punjabi and so on. Most of the teachers have reported a low proficiency level of an L2 or L3, such as French, Spanish, Japanese and so on. However, only Chris reported a high proficiency level of an L2 and L3, i.e., Japanese and French. This echoes with his 23 years of past teaching experience of ESL in Japan.

5.1.6 Summary of teacher background

Most of the 15 teachers are young and inexperienced. They have recently started EMI science teaching in China, with generally limited past EMI teaching experience elsewhere. Only a few teachers have taught for a number of years in their home countries (e.g., Kate, Louis). About half of the teachers have had some short ESL/EFL training and teaching experiences. Most also reported experience of learning an L2, or L3, themselves. This indicates that many of the 15 teachers may have some level of awareness and understanding of language teaching and the non-native English speaking students' needs. However, none of them had EMI training.

5.2 Teachers' beliefs about effective teaching of science

This section presents the findings of Section 1 of the teacher beliefs questionnaire on teachers' beliefs about effective teaching of science.

5.2.1 Multiple-choice questions 1-16

The overall mean score for the multiple-choice questions is 3.8 out of 5, with a standard deviation (SD) of 1.0. This suggests an overall clear constructivist belief about teaching science and a

fairly narrow spread of opinions among the teachers. Some subscales demonstrated a more constructivist view than others, which will be explained below.

Table 44 below presents the descriptive statistics of all the multiple-choice items, organized by subscales. The mean answer is shown of each item to provide direct examination of the teachers' original answers. The mean score is shown of each subscale to demonstrate the degree of alignment of the teachers' answers to the constructivist view of teaching science.

Item	**Mean answer (SD) n=**
Subscale 1: Role of previous knowledge **(Mean score: 3.8, SD: 1.1)**	
2.When introducing a new topic, asking students about their existing knowledge about the topic is **NOT** necessary.	1.9 (1.0) n=15
5.Students have difficulties learning scientific concepts mainly because their ideas about how the world works are often resistant to change.	2.6 (1.1) n=15
6.When teaching a new topic, making reference to students' preconceptions is **NOT** necessary.	1.9 (0.7) n=15
11.Teachers should **NOT** let students' existing understandings, or their difficulties determine the direction and the focus of lessons.	1.9 (0.5) n=15
15.Telling students' new knowledge upfront is more effective than helping students construct their own understanding based on their existing knowledge.	1.9 (0.8) n=15
Subscale 2: Role of practical activities **(Mean score: 2.2, SD: 0.9)**	
7.Students should explore and conduct their own experiments with hands-on materials before the teacher discusses any new scientific concepts with them.	2.9 (1.0) n=15
9.Experiments should be included in lessons as a way to reinforce the scientific concepts students have learned in class.	4.5 (0.5) n=15
Subscale 3: Role of interaction: students' substantial output **(Mean score: 3.9, SD: 0.6)**	
8.In most classes, students' substantial verbal explanations of their ideas are **NOT** necessary. Having short verbal answers from students is good enough.	2.8 (0.9) n=15
10.In most situations, teachers should do most of the talking in class.	1.7 (0.6) n=15
13.Teachers' elicitations of substantial verbal answers from students to explain our views are **NOT** necessary for my learning.	1.9 (1.0) n=15
Subscale 4: Teacher-student interaction vs teacher monologues **(Mean score: 4.2, SD:0.8)**	

1.Interaction between teacher and students is important for learning science.	4.7 (0.5) n=15
3.In most situations, teacher's monologue of explanation is more effective and helpful for my science learning than teacher-student interaction.	2.2 (0.9) n=15
Subscale 5: Student-student interaction **(Mean score:4.4, SD: 0.8)**	
4.It is **NOT** useful for us to discuss and debate multiple possible answers with each other in class.	1.7 (0.7) n=15
12.Interaction between students and students is **NOT** important for learning science.	1.6 (0.8) n=15
Subscale 6: Role of teacher questions **(Mean score: 4.2, SD:1.2)**	
14.Most of the questions in my science classes should be about asking us to recall information.	2.1 (1.2) n=15
16. Teachers' questions that require us to compare and identify relationships between concepts are **NOT** necessary.	1.5 (0.6) n=15

(1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

Table 44 Descriptive statistics of Section 1 of teacher beliefs questionnaire

Subscale 1 demonstrates that the teachers held a generally clear constructivist belief about the role of students' prior knowledge. Most teachers clearly recognized the importance of considering students' prior knowledge when teaching new science concepts, as shown in Items 2, 6, 11 and 15. However, in Item 5, with a mean answer of 2.6, only four teachers acknowledged that a main cause of students' difficulties of learning science is that students' preconceptions are resistant to change. This subscale reveals teachers' clear constructivist understanding of the general importance of students' prior knowledge, but a lack of a thorough understanding of the major role it plays.

Subscale 2 is the only subscale where an overall transmissionary view was shown, with a mean score of 2.2 out of 5. Item 7, describing the constructivist use of practical activities, received a wide spread of opinions among the teachers, resulting in a neutral mean answer of 2.9. However, Item 9 shows the teachers' unanimous belief about the transmissionary use of practical activities. This subscale overall reveals a more transmissionary belief on the issue of practical activities among the teachers.

Subscale 3 shows teachers' general recognition of the importance of students' substantial output for science learning. Most teachers acknowledged the value of students' substantial explanations of their views in Items 10 and 13. However, a weaker constructivist view was shown in Item 8, with a more neutral mean answer of 2.8. This could be because that Item 8 explicitly differentiates short answers and substantial answers. Four teachers agreed that short answers were good enough. This subscale reveals that when short answers are presented as an option, some teachers might not hold a firm constructivist view.

Subscale 4 shows teachers' strong acknowledgement of the importance of teacher-student interaction for science learning. In Item 1, all teachers agreed or strongly agreed. In Item 3, 11 teachers demonstrated the constructivist view that in most situations teachers' monologues should not replace teacher-student interaction. This slightly weaker constructivist view in Item 3 could be because teacher monologues were presented as an option and some teachers were attracted to this idea.

Subscale 5 on student-student interaction showed the strongest constructivist belief among the teachers, with a mean score of 4.4. Most teachers acknowledged that discussion among students themselves to debate multiple perspectives is important for science learning, shown in both Items 4 and 12.

Subscale 6 on teacher questions also reveals a strong constructivist belief. Most teachers disagreed with recall questions being the main type of teacher questions in Item 14 and almost all teachers agreed higher-order thinking questions are necessary in Item 16.

5.2.2 Summary of teachers' beliefs about the effective teaching of science

The findings of Section 1 of the teacher beliefs questionnaire show that most teachers held a clear constructivist belief about teaching science and valued the role of interaction. When a more transmissionary view was presented as an option, such as students' short answers and teachers' monologues, some teachers were less firm about the constructivist belief about the role of students' substantial output and teacher-student interaction. The subscale where a transmissionary view was clearly recognized is the use of practical activities.

5.3 Teachers' beliefs about effective English language teaching in EMI science classes

This section presents the findings of Section 2 of the teacher beliefs questionnaire on language teaching in EMI science classes.

5.3.1 Multiple-choice questions 1-20

Section 2 has an overall mean score of 3.9 and a standard deviation of 0.9. This suggests an overall favourable belief about English language teaching in EMI science classes among the teachers. Table 45 below presents the descriptive statistics of the answers to each item, and the descriptive statistics of the scores of each subscale.

Item	**Mean answer (SD) n=**
Subscale 1: Teachers' proficiency of the language of science **(Mean score: 3.3, SD: 1.5)**	
19. I need to have better proficiency of using the language of science (i.e., the specific way of using language to talk about science).	2.7 (1.5) n=15
Subscale 2: Teachers' knowledge about the English language and attitudes towards it **(Mean score: 4.2, SD: 0.9)**	
14. EMI science teachers do **NOT** need to have knowledge about English grammar.	2.5 (1.4) n=15
16.EMI science teachers do **NOT** need to know about the way English is pronounced.	1.9 (0.7) n=15
18.My explicit knowledge about how English language works is good.	4.3 (1.0) n=15
Subscale 3: EMI students' language difficulties	
3.1 Teachers' recognition with the areas of language EMI science students need help with (Mean score: 3.8, SD:0.9)	
3.The language of science (i.e., the specific way of using language to talk about science) in English is **NOT** a problem for my students.	2.1 (1.1) n=15
4.The general use of English language (not science-specific language) is a problem for my students in learning science through English.	3.3 (1.0) n=15
8.Explaining difficult words in textbooks or text-based notes to my students is helpful.	4.5 (0.5) n=15
9.Teaching my students English grammatical structures commonly used in science texts (e.g. passive voice) is **NOT** important.	2.7 (0.8) n=15
10. Modelling ways of using English language to develop arguments in science to my students is important.	4.0 (0.7) n=15
3.2 Teachers' attitude of the need to know about EMI students' language difficulties **(Mean score: 4.0, SD:0.6)**	
15.I should have knowledge about my students' difficulties in learning English grammar.	3.9 (0.7) n=15

17. I should have knowledge about my students' difficulties in pronouncing English.	4.1 (0.7) n=15
20. I do **NOT** need to know about my students' difficulties in learning the language of science.	1.8 (0.4) n=15
Subscale 4: EMI teachers' role as a language teacher (Mean score:3.7, SD=0.9)	
1.I need to focus on science in my science classes, **NOT** English language.	2.6 (0.9) n=15
2.It is **NOT** my task to teach the academic language required for learning science in English (e.g., the English language used in writing a chemistry lab report, describing phenomenon etc.) in my EMI science classes.	1.9 (0.5) n=15
5.English language learning objectives should **NOT** be included as part of the lesson objectives in my science classes.	2.3 (1.0) n=15
Subscale 5: The role of interaction **(Mean score: 3.9, SD=0.8)**	
6.I would correct students' **oral** English in my science classes to improve their English.	3.5 (0.8) n=15
7. I would correct students' **written** English in my science lessons to improve their English.	3.2 (1.1) n=15
11.1). Students' **spoken** English language output is unnecessary for improving their English.	1.9 (1.1) n=15
11.2). Students' **written** English language output is unnecessary for improving their English.	1.7 (0.8) n=15
12. In EMI science lessons, students do **NOT** need regular opportunities to talk about science in English.	1.7 (0.6) n=15
13.1).Having students do work in science that requires them to give long **spoken** answers in English is helpful for them to improve their English.	3.7 (0.9) n=15
13.2). Having students do work in science that requires them to give long **written** answers in English is helpful for them to improve their English.	3.9 (0.6) n=15

(1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

Table 45 Descriptive statistics of Section 2 of teacher beliefs questionnaire

Subscale 1 shows teachers' limited confidence about their own proficiency of the language of science. With a mean answer of 2.7 for Item 19, only 9 out of the 15 teachers thought their proficiency of using the language of science was good enough.

Subscale 2, with a high mean score of 4.2, shows that the teaches were confident about their knowledge about English language and held a strong belief that EMI science teachers should

know about the English language. Among the three items, Item 14 shows a less favourable view for language learning in EMI science classes, where five teachers did not consider it important to have knowledge about grammar as EMI teachers.

Subscale 3.1 shows that the language of science received more consistent acknowledgement from the teachers as an important area of language to teach than general English, and vocabulary was regarded more important to teach than grammar. Item 4 shows that only seven out of the 15 teachers acknowledged that general English is also a challenge for EMI science students, resulting in a more neutral mean answer of 3.3. Item 8 shows all teachers acknowledged explanations of difficult vocabulary in textbooks are important while Item 9 shows only eight teachers acknowledged the need of explicit instruction of the grammar features that are common in science texts. However, modelling ways of using English to construct science ideas, described in Item 10, was considered important by most teachers. This reflects that the teachers perhaps were more inclined to demonstrate grammar rules through communication about science ideas than explicit instruction.

Subscale 3.2, with a high mean score of 4.0, shows teachers' strong belief that EMI science teachers should know about their students' language difficulties. Most teachers recognized that they should know about their students' difficulties with grammar and pronunciation, and all teachers agreed that they should know about their students' difficulties with the language of science.

Subscale 4 has the lowest mean score, 3.7, showing that the teachers had a limited level of recognition of themselves as language teachers. Item 1 shows that only eight teachers considered English language as a focus in their EMI science classes. Similarly, for Item 5, only nine teachers acknowledged that English learning objectives should be included as part of lesson objectives. However, Item 2, specifically enquiring about the teaching of academic language required to learn science, shows most teachers recognized it as their task. Thus, this subscale shows a content-driven view about language teaching among the teachers and that some teachers were mostly concerned about the teaching of the language features that are directly related to science learning.

Subscale 5 shows the teachers' overall clear recognition of the important role interaction plays for language development. A clear majority of the teachers recognized the importance of students' spoken and written output for improving language learning, as shown in Items 11 (1), 11 (2), and 12. However, fewer teachers held the same belief about students' substantial output. Only 9 teachers recognized students' lengthy spoken output is helpful and 10 teachers recognized the value of lengthy written output. The role of spoken and written corrective feedback was also recognized only by nine and seven teachers, as shown in Items 6 and 7.

5.3.2 Open-ended question 21

Question 21 in Section 2 of the teacher beliefs questionnaire compares monolingual teachers and bilingual teachers. Different views were shown among the teachers. Eight teachers selected 'c'. Three selected 'a' and four selected 'd'. Thus, eight teachers preferred having a native English speaking teacher who does not speak Mandarin, while the rest believed it was better to have a teaching assistant or bilingual teacher who can use Mandarin to help but still use English as the main medium of instruction.

Among the reasons given by the teachers in support of a monolingual teacher, i.e., using English only, the most common ones are that the use of the students' L1 would lead to students' dependence on it and reduce their engagement with English. They held the idea that an all-English environment was the most ideal for students' English learning. For example, Christina mentioned that '*students might not interact with you in English*' if they knew Chinese was available. Louis explained that '*an all English environment forces students to learn English better*'. The future of attending an all-English university was another common reason mentioned by multiple teachers to disapprove the use of students' L1.

The common reasons for preferring a bilingual teacher or a bilingual teaching assistant are that L1 could be used for explaining difficult vocabulary and concepts, and students could provide L1 translations for each other. The teachers in favor of the use of L1 also specified that due to their students' low English proficiency level, the use of L1 during group discussion could help

the students to freely express science ideas before reporting back to the teacher in English. Most of the teacher who opted for a bilingual teacher or teaching assistant also mentioned that L1 should only be used when necessary and most of the instruction should still be in English.

5.3.3 Summary of teachers' beliefs about effective teaching of English in EMI science classes

An overall favourable view of developing students' English competence in EMI science classes was shown. Most teachers recognized the important role of interaction for language development. However, a less favourable view was shown regarding providing corrective feedback and the role of students' substantial output. The teaching of the language of science received stronger recognition than general English, and teaching of vocabulary was recognized more than the teaching of grammar. Limited identification was found among the teachers as language teachers.

The teachers were also found to hold diverse views regarding L1 use and monolingual vs bilingual teachers. More than half of the teachers showed preference for a monolingual teacher, i.e., teaching only through English. They believed a full immersion environment is most helpful for students to practice and develop their English skills. Reliance on L1 was seen inhibiting students' English learning. In contrast, other teachers regarded L1 as a helpful tool, which could be used by the teachers to explain difficult vocabulary and by the students to provide L1 translations for each other to help them express their science ideas more freely.

5.4 Findings from the teacher interviews

While the teacher beliefs questionnaire produced results on the teachers' beliefs about effective science and language teaching in EMI science classes, interviews with the teachers also showed insights on their personalized beliefs and allowed them the space to bring issues which were not covered in the questionnaire but were important in their discussion of their beliefs. The following themes emerged from the pre-lesson interviews, post-lesson interviews, and the general interviews with the 15 teachers, which also represent the structure of this section.

5.4.1) Teachers' beliefs about teaching science in EMI classes

5.4.1.1).The role of interaction

5.4.1.2) Strategies for facilitating interaction in EMI classes

5.4.1.3) Making abstract concepts concrete

5.4.1.4) The use of practical activities

5.4.2) Teachers' beliefs about teaching English in EMI science classes

5.4.2.1). The role of interaction

5.4.2.2) Explicit teaching of vocabulary

5.4.2.3) Use of assessments

5.4.2.4) Teachers' identification of their role as a language teacher

5.4.3) Teachers' views of the use of L1

5.4.4) Difficulties of translation of beliefs into practice

5.4.4.1) Difficulties of using interaction

5.4.4.2) Difficulties of using practical activities

5.4.4.3) Teachers' understanding of the students' language difficulties

5.4.5) The influence of Chinese medium instruction (CMI) science classes and the grade level on classroom interaction

5.4.5.1) The influence of the CMI science classes on teacher-student interaction

5.4.5.2) The influence of the grade level on teacher-student interaction

As explained in Chapter 3 Methodology, in the foreign high school programs students often study the Chinese provincial high school curriculum that runs in parallel with the foreign high school curriculum. Thus, whether the availability of having CMI science classes makes an impact on the teacher-student interaction in EMI science classes was enquired about. In addition, as all teachers' lessons observed were from one grade level, the influence of grade level on teacher-student interaction was also enquired about.

In the presentation of the findings from teacher interviews, connections will be made with relevant findings from the teacher beliefs questionnaire.

5.4.1 Teachers' beliefs about teaching science in EMI classes

Based on the transcripts of the interviews and the coding of the themes, the answers from teachers' interviews demonstrate the teachers' strong constructivist idea with clear recognition of the value of interaction and a focus on making abstract science ideas concrete for students (e.g., using diagrams and visual aids). The commonly mentioned effective strategies of teaching science include exploring students' existing knowledge, asking open-ended questions, adjusting teaching according to the students' responses, encouraging students to work with each other to solve

problems, teaching through practical investigations and having students test their own hypotheses, and helping students apply their knowledge. These constructivist understandings are elaborated below, followed by strategies for making abstract science ideas concrete. Among these strategies, teachers' awareness of the EMI students' language needs was also often reflected.

The role of practical activities was also commented on in the teacher interviews, which also contributes to understanding the monolingual science teachers' beliefs about effective science teaching in EMI contexts. Both constructivist view and transmissionary view of practical work were demonstrated among the teachers.

5.4.1.1) The role of interaction

Similar to the findings from the teacher beliefs questionnaire, the important role of interaction for science learning was consistently acknowledged. Several teachers mentioned it was critical to interact with students to get to know their existing knowledge, which then directs their subsequent teaching. Mat, a Biology teacher at School 7, commented on a concrete example in one of his lessons observed where he checked whether students already knew the concept 'clone' before introducing it. He mentioned in a post-lesson interview that:

> '*Clone is one of these words that I would assume are common in English language. I don't want to assume that every concept I teach is new. They probably have got this from previous Biology lessons in junior secondary school or just a newspaper or TV, so that's why I like to ask them before I teach.'*

Mat's comment above reflects his awareness of the importance of exploring students' previous knowledge and adjusting his teaching accordingly.

The accentuated role of exploring students' existing knowledge in the EMI contexts was also emphasized. Aaron, a Biology teacher from School 6, provides a clear illustration – '*Because you need to check their knowledge, especially for non-native English speakers. I need to know that they understand the material. The interaction helps me understand what they are not clear about.'* Other teachers also mentioned that by asking even simple questions they could understand the depth of students' understanding and identify the students who are struggling, which informs their subsequent teaching.

The use of questioning was another area that was frequently commented on. A few teachers elaborated on the importance of asking open-ended questions to encourage output from students and discussion among themselves to promote students' own thinking to solve problems, which also aligns with the findings from the teacher beliefs questionnaire. Many teachers emphasized the value of having students' work on problems themselves among groups rather than telling students directly the solutions. A typical quote is as follows, by Colin, a Physics teacher from School 1:

> '*There needs to be lot of inquiry, a lot of opportunities to discuss, and to have students ponder, and to ask them open-ended questions. And to be able to listen to their responses to that. To listen to them work with each other to try to solve problems, and to understand what they are seeing*.'

This quotation demonstrates the teacher's recognition of the value of providing ample opportunities for students to discuss ideas themselves, asking open-ended questions to encourage thinking and understanding where students are in their learning.

Other strategies regarding the use of questions include breaking down a general question into smaller questions, which was commented as particularly helpful for EMI contexts. Asking a series of more specific questions rather than a general question was commented as helpful for EMI students to compose their answers step by step. Similar to the important role of teachers' questions, creating opportunities for students to ask questions was also commented on by a few teachers as important for effective science teaching. Several teachers highlighted the importance of building a trusting relationship with the students, which would help students feel comfortable with asking questions.

Another theme that emerged from the interviews is that the ultimate goal of learning science was to help students apply their knowledge and develop skills to become independent learners rather than focusing on knowing all the detailed facts. A typical explanation is from Nicolas, a Biology teacher in School 5:

> *'It's about understanding the value of what they are learning, not necessary about remembering all the little facts, but understanding why, and apply them. Do you understand how the facts relate to other things and are they able to make educated guesses, and even if they don't know something, would they be able to go look it up and become self-learners?'*

This explanation above shows how Nicolas viewed the goal of learning science, which is to help students become self-learners and be able to apply what they learn to unknown situations. This view was also reflected in other teachers' answers.

5.4.1.2) Strategies for facilitating interaction in EMI classes

While interaction was clearly recognized as crucial for teaching science, various strategies were also mentioned by the teachers as especially helpful for facilitating interaction in the EMI contexts, demonstrating their awareness of the EMI students' difficulties of learning complex science matter through an L2. Certain comments mentioned in the previous section could also be seen as strategies for EMI contexts, such as breaking down a general question into smaller

ones and checking students' previous knowledge. Other common strategies mentioned by the teachers included input modification strategies, such as using repetition, providing examples, spending substantial time explaining vocabulary, providing shorter and simplified notes and worksheets and so on. Output elicitation strategies were also mentioned, such as prioritizing the communication of science ideas and scaffolding students' answers by providing the language items needed.

The use of repetition and lots of examples to ensure comprehension was commented as an important strategy for teaching in the EMI contexts. The teachers frequently mentioned they would repeat key content knowledge from various sources, e.g., worksheets, textbooks, videos, and going over one concept with different examples. George, a Biology teacher from School 4, provided a concrete example:

> *'I just need to repeat a lot of things, just to make sure they have comprehended what I said…Like if I'm talking about sugar…I will just keep talking about these certain things about carbohydrate…I'll talk about fruits, I'll talk about bread, I'll talk about cookies. I'm like all these things have carbohydrate. Or you could call it sugar…I will just keep saying the word, carbohydrate, carbohydrate.'*

He explained that going over and over one concept with different examples and repeatedly saying the key concept words to the students were among the most effective methods of teaching science in EMI classes. This demonstrates his awareness of the language difficulty EMI students face and the importance of maximizing the exposure of key terminologies for L2 learners.

The substantial effort for explaining vocabulary was another main strategy mentioned. A quote from Chris, a Chemistry teacher from School 4, clearly demonstrates this:

> *'I wouldn't be spending that much time if I were teaching, you know, native English speakers. I mean for sure the technical terms I would spend a little time, but in general, I wouldn't be spending nearly as much time as I spend in these classes. I wouldn't spend that much time defining the words.'*

Similarly, several teachers also mentioned the need to explain vocabulary items which would normally be familiar to L1 students. Jenny, a Chemistry teacher from Canada at School 7, provided a concrete example:

> '*The purpose of buffers is to resist the change of PH right. Now I've taught the Canadian students and I am not gonna be concerned about any words whereas if I would explain it here in China, I am gonna ask 'ok, did you understand what I said?' They would be like 'Ah, no, what does resist mean?'*

This example shows how some teachers perceived that EMI students would have problems with non-technical vocabulary like '*resist*' in teachers' science explanations and the need to explain everyday non-technical vocabulary that would normally be known to L1 students. This provides explanations of the questionnaire finding where about half of the teachers did see general English a problem for their EMI students. More details on this topic will be given in Section 5.4.4.3) Teachers' understanding of the students' language difficulties.

Due to the often-reported students' low English proficiency, a coping strategy was also mentioned by a few teachers to not require accurate use of English in the students' output but to prioritize the meaning of the students' messages to encourage interaction. A typical quotation is from Colin, a Physics teacher from School 1:

> '*I would try to encourage them to understand they don't have to have perfect grammar. They don't have to have perfect pronunciation. In science, we are using language as a tool…You can help them with their language, but it's not forefront…Well, it takes a lot of work and imagination from the teacher's perspective to listen to what they are saying and understand that they are saying through limited vocabulary.'*

This comment demonstrates the teacher's idea of valuing students' output and participation in classroom talk when the students had limited English proficiency. The attitude of not requiring accurate use of grammar also in a way explains the questionnaire finding earlier where about half of the teachers did not regard it important to teach grammatical structures common to science texts. The low recognition of the need to teach grammar could be because that the teachers would not require their students to use accurate grammar and only saw language as a

tool and not at the forefront of their teaching.

Other strategies commented as particularly useful for the EMI contexts include preparing shorter notes to reduce the language barrier, providing shorter and simpler definitions of concepts, showing questions on the screen as students might find it hard to comprehend the questions spoken to them. Some of these strategies particularly for the EMI context are also related to the issue of language teaching in EMI science classes. Because of the intertwined nature of content and language, it is difficult to make a clear division between the teachers' perceived effective strategies for science teaching and language teaching. The division was made here based on where the teachers' answers came up, i.e., either provided to answer the questions about science teaching or language teaching.

5.4.1.3) Making abstract concepts concrete

Apart from the answers which reveal a constructivist idea of teaching science, another major focus in the teachers' answers was making abstract science concepts concrete. Many teachers mentioned the strategies of making use of diagrams, videos, and simulations (i.e., software that allows the manipulation of variables and simulates the lab situation), and relating new science concepts to previously taught concepts. Johnson, a Physics teacher at School 7, provided a concrete example of how he made use of a previously learnt concept (i.e., gravitational force) to illustrate a new abstract concept (i.e., electricity). He mentioned:

> *'With electricity, it's a very abstract concept. So, what we've been doing is making a connection with something more familiar like gravity. So, we are taking electricity and the electric force, ensuring how it's very similar to the gravitational force. Something that they are more familiar, more comfortable with.'*

The quotation above demonstrates the teachers' awareness of the difficulty of understanding abstract concepts and their strategy of making comparisons with a concept the students are familiar with.

5.4.1.4) The use of practical activities

The use of practical activities was also commented on by several teachers. Similar to the questionnaire finding, some teachers demonstrated a constructivist view and some showed a more transmissionary view of using practical activities in the interviews.

Several teachers demonstrated a constructivist view of practical activities through explaining the importance of using them as a way for students to analyse and interpret data to draw conclusions. A typical quotation is from Louis, a Chemistry teacher from School 3:

> *'I think it's important to let them see the practical applications…You don't just collect data so you can put it on chart, you collect data so you can use it to say why you think this way and that's a fundamental part of how science works.'*

This quotation demonstrates the teacher's view of the importance of analysing data to support or refute hypotheses. Similarly, Hannah, a Biology teacher at School 7, mentioned that making and explaining hypotheses was a major component in using practical activities – '*Before they do a lab, they should have a basic understanding about the purpose of the lab. They should have some hypotheses on what they are gonna see, and they should be able to justify their hypotheses.'*

While a constructivist view was shown among some teachers, others showed a more transmissionary view of practical activities and regarded them a way to reinforce new concepts introduced. A typical explanation is from Jenny, a Chemistry teacher at School 7, - *'Labs are very valuable because they allow students to remember and appreciate the knowledge… So, first lecture and then have them apply their knowledge throughout the lab activity.'* Here, lab was seen a way to demonstrate and reinforce new knowledge or concepts learnt in class, which helps students to memorize them.

In summary, in the comments about practical activities, both constructivist view and transmissionary view were reflected. This finding also provides insights of the similarly diverse views shown in the subscale *the role of practical activities* in the teacher beliefs questionnaire, where the constructivist use of practical activities was perceived differently among the teachers. However, as Item 9 of the subscale shows, all teachers supported the transmissionary use of practical activities to reinforce the knowledge taught. Combining the explanations provided in the interviews and the questionnaire, it seems that in the interviews while the constructivist idea of using practical activities was only held by several teachers, they might also at the same time approve of a transmissionary view of using practical activities. This means that some teacher recognized both the constructivist and transmissionary views and some only believed in the transmissionary use of practical activities.

5.4.2 Teachers' beliefs about teaching English in EMI science classes

While Section 5.4.1 Teachers' beliefs about teaching science in EMI classesabove presents the interview findings about teachers' beliefs about effective science teaching from the interviews, this section introduces the teachers' perceived effective ways of teaching English in EMI science classes. An overall favourable view of facilitating students' learning of English in EMI science classes was demonstrated, with a clear recognition of the value of interaction. Input modification strategies were shown to be the teachers' main focus. In comparison, the importance of having student output and providing corrective feedback was acknowledged to a lesser degree. Similar to the findings from the teacher beliefs questionnaire, a strong focus was shown on explicit teaching of vocabulary whereas limited attention was given to the teaching of grammar. The theme of using assessments to enhance language learning in EMI science classes also emerged. Although the concern for students' language learning was clear, the teacher demonstrated various degrees of direct identification as a language teacher.

5.4.2.1) The role of interaction

Similar to the questionnaire finding, most teachers acknowledged the importance of interaction for language learning. In the interviews, they particularly highlighted the

importance for students to be exposed and immersed in the English language, especially because they did not have this language environment outside of classrooms. As mentioned in Section 5.4.1 above, the intertwined nature of content and language in EMI classes makes it difficult to clearly separate the themes of teaching science and teaching English. The division was made based on where the answers were provided by the teachers in the interviews, either to a question in the science domain or the language domain. It is acknowledged that certain strategies could be serving both purposes of aiding science learning and language learning.

Input modification strategies were the main component of interaction that was commented on, and these strategies mainly concerned the adjustment of the use of vocabulary, e.g., using synonyms, pictures or videos to illustrate the meaning of certain words. Aaron, a Biology teacher at School 6, provided a clear explanation on how he used synonyms to explain more advanced vocabulary:

> *'I think the main difficulty is the limitation of vocabulary…They know the word car, but they may not know automobile, right? A truck or van, like these are different ways of saying the same thing. So, I have to be careful when I use different terms. I also need to introduce the words that they may not know, so, like automobile.'*

He also provided another example - *'I use 'blood stream' because that's common English. So sometimes I say, what happens when you inject this substance into the blood stream? The blood stream, what's that? Oh yes, blood vessel, blood circulation, right?'* This strategy of using a more common everyday English synonym for more sophisticated vocabulary was often commented on by the teachers. This demonstrates the teachers' strong awareness of the input modifications of vocabulary to aid students' comprehension. It needs to be noted that the examples of vocabulary given in the teachers' interview that were rendered comprehensible included not only the technical vocabulary or phrases, such as *blood vessel*, but also sometimes non-technical vocabulary, such as *automobile*. This theme was also mentioned in Section 5.4.1.2 earlier.

The students' lack of vocabulary was recognized by several teachers and effort of expanding their vocabulary repertoire was also frequently mentioned, such as introducing synonyms and

explaining the everyday vocabulary that appear in word problems. Again, the problem of common non-technical vocabulary was specified by several teachers. It was mentioned that even simple everyday words (e.g., *ramp*) may be unknown to the EMI students and cause difficulties in comprehending a word problem (e.g., *pulling a trolley up a ramp*). A clear explanation was provided by Johnson, a Physics teacher at School 7:

> '*There are a lot of common words that I think are easy to western students that the Chinese would not be familiar with. So, we need to build their common vocabulary…For example, we talked about 'pulling a trolley up a ramp' in one of the word problems in the lesson. Students did not know the word 'ramp'. We can also call it a slope, a hill. So, there are all these different words.'*

This view of expanding the students' common vocabulary through introducing different synonyms suggests a more language-driven approach of teaching English in EMI science classes adopted by several teachers. Here, language teaching was not always motivated by an immediate need of content knowledge comprehension but by the opportunities presented through content learning, such as unknown vocabulary used in word problems and the different synonyms of it. The clear awareness of the students' lack of non-technical vocabulary demonstrated by several teachers in the teachers' interviews ethos with the findings from the teacher beliefs questionnaire where about half of the teachers acknowledged general English was a problem for EMI students. The teachers who acknowledged this problem did provide thorough and clear explanations in the interviews, thus explaining the choices made by some teachers in the beliefs questionnaire.

While most teachers highlighted the importance of adjusting the use of vocabulary their EMI classes, some teachers also emphasized the importance of not limiting the kind of vocabulary they use in their EMI classes. A clear explanation was provided by Louis, a Chemistry teacher from Canada:

> '*Like in one of my classes, I used the phrase 'diddly squat'. Diddly means nothing. So, if you did diddly squat, it means you did nothing. If I use that at home, I know everyone's going to understand that. But here I have to assume that nobody knows that…But here I would still use them. I will stop and explain them. It's important for them to be exposed*

to new words.'

Louis argued that he would not limit his use of vocabulary because an idiom is unknown to the students. Instead, he would still use the expressions he would use in Canada to expose students to colloquial expressions used there and explain them.

Apart from input, the role of students' output was also recognized in the teachers' interviews. A few teachers explained the value of students' practice speaking and communicating with each other through English. Several teachers mentioned although the students' output took time due to their limited English proficiency, they still regarded it important that the students practice using English themselves rather than only receiving input from the teachers. However, the third component of interaction, feedback, was rarely mentioned in the interviews. This reflects the teachers' possible limited awareness of the value of corrective feedback for students' language learning, which also echoes with the limited recognition shown in the teacher beliefs questionnaire. It also may indicate that the explicit teaching of language might not be a priority for most teachers. The theme of teacher's identification as a language teacher will be elaborated further in Section 5.4.2.4.

5.4.2.2) Explicit teaching of vocabulary

An explicit effort of teaching vocabulary was another major area the teachers commented on, which also echoes with the questionnaire finding where explanation of difficulty vocabulary was unanimously considered important by the teachers.

In the interviews, several teachers mentioned they regularly put aside lesson time to explain the new vocabulary in a new chapter or in the textbook pages that were assigned for the students to read. A common practice mentioned was using a vocabulary worksheet and having students look up the key vocabulary at the beginning of a new chapter. An example is given in Appendix 19. As can be seen there, this vocabulary worksheet designed by Colin includes both technical vocabulary in the new chapter, such as *mass* and *force*, and non-technical vocabulary which was also in the new chapter and was regarded as new to his students, such

as *repeat* and *independent*. Students would typically be asked to write down the definition of these new key vocabulary, having consulted the glossary list (see an example in Appendix 20) at the back of their textbooks and dictionaries.

A detailed account of explicit teaching of vocabulary was provided by Chris, a Physics teacher at School 4. His routine included eliciting difficult words from the students which they encountered in the textbook. Then, he would type the explanation or definition of these words on his laptop, which was projected to the white board. This practice mentioned in the interview was also observed in one of his lessons. A screenshot of how Chris typed up explanations of words in one of his lessons is shown below in Figure 22.

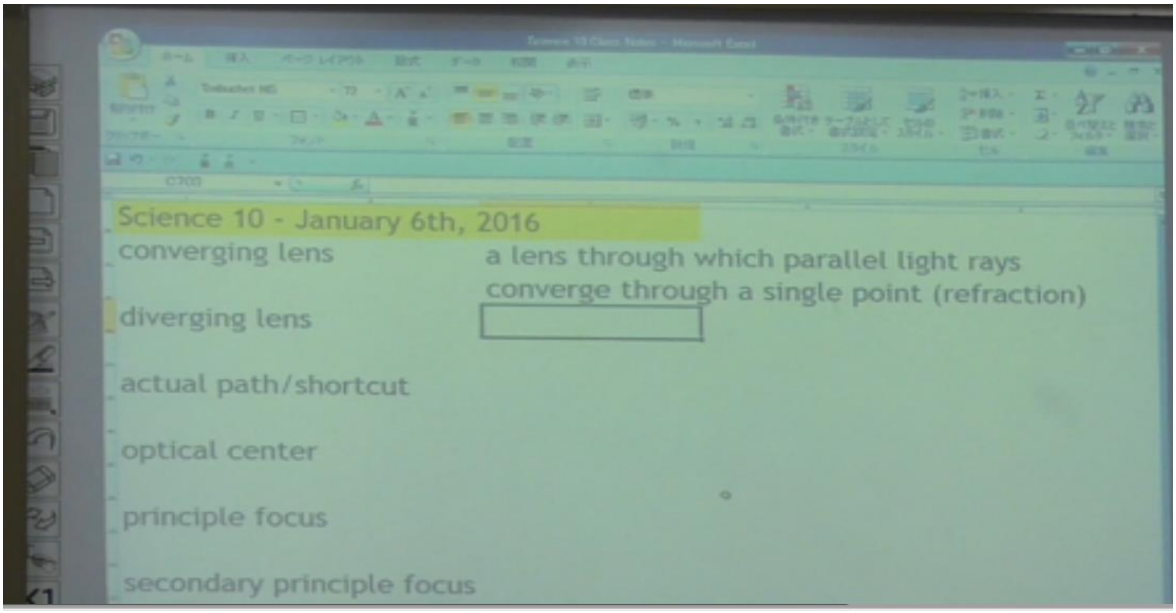


Figure 22 a screenshot of Chris's practice of typing explanations of difficult words proposed by students

All the phrases, e.g., *converging lens, shortcut, optical centre*, were difficult items suggested by the students. Similarly, some of these vocabulary items were non-technical, such as *shortcut*, and some were technical vocabulary, such as *converging lens* and *optical centre*, which could concern not just the language challenge but also the challenge of understanding the actual science ideas.

5.4.2.3) Use of assessments

Another theme that emerged from the teacher interviews was incorporating the comprehension and production of English in assessments. The use of vocabulary quizzes was often mentioned. Because of her students' weak English proficiency, Christina, a Biology teacher at School 7, provided a clear description of how she had her students take weekly vocabulary tests to focus specifically on vocabulary learning:

> *'I started to give a weekly vocabulary test, which actually is counted in their final grades. I think it is important to do so because that's their only problem and they had better learn the words. How can they do well in the provincial exam if they don't even understand the questions being asked?'*

Similarly, Colin also mentioned that he would incorporate the task of comprehension of the language in his quizzes. He provided an example of how, in a quiz about gravity (see Appendix 21), the full name of certain formulae (e.g., the law of universal gravitation) are provided in Section 1 and students were asked to match the actual formula to the names. In this way, as Colin explained, the students had to understand the English names of these mathematical formulas. Similarly, Section 2 of the quiz, where a list of statements is provided, requires comprehension of these statements in English. The purpose was explained to incorporate the comprehension of the English language rather than simply asking students to produce a number as their answers. Similar practices were also mentioned by other teachers of having vocabulary quizzes or integrating the comprehension of English and production of English in assessments.

5.4.2.4) Teachers' identification of their role as a language teacher

The findings presented above on the role of interaction for language learning, explicit teaching of vocabulary and the use of assessments already in a way reflect the teachers' concern for their students' language learning in EMI science classes. The direct comments on their identity,

however, show varying degrees of identification among the teachers of their role as a language teacher, which echoes with the findings from the teacher beliefs questionnaire.

Several teachers mentioned that their job heavily involved teaching English and addressing the language barrier. A significant imbalance was observed between their students' solid subject content knowledge and their limited English, and this seemed to have contributed to some teachers' stronger identification of themselves as a language teacher. A clear explanation was provided by Kate, a Biology teacher at School 1. She mentioned that her main role was actually teaching English:

> '*The Chinese students have the skills and knowledge to do what we need to do in the science class. What they need to learn is how to do it in English now. They need to know the English vocabulary for everything. That's actually the main role for my teaching.'*

While some teachers demonstrated clear identification of their role to teach English, others showed less identification where they only saw explaining difficult vocabulary as their duty in terms of language teaching. A typical quotation was from Aaron, a Biology teacher at School 7:

> '*I do, to some extent, pay attention to the difficult vocabulary. But about syntax, no I don't, I don't correct their sentences… If I can understand it, and they answer it correctly, I will give them a point. If I can't understand it, then I, which I think is rare, actually. Then I will talk to them for clarification.'*

Here, Aaron recognized the need to teach vocabulary but not beyond that (e.g., syntax etc.). Other teachers also expressed similar views, having explained that their lessons were not grammar lessons and sentence structures were not talked about, and they would prefer showing

students how to use certain vocabulary through their own speech rather than explicit instruction.

Overall, diverse opinions were shown in the interviews regarding teachers' identification of their role as a language teacher. The consistent theme was that the explanation of difficult vocabulary was considered necessary, but the teaching of grammar was explicitly mentioned by several teachers as not their task as science teachers. The varying degrees of identification also echoes with the results in the teacher beliefs questionnaire, where a relatively low average score of 3.7 and a spread of different views were shown in the subscale d '*EMI teachers' role as a language teacher*'.

5.4.3 Teachers' views of the use of L1

The issue of using students' L1 was also frequently commented on. A divide was observed with a group of teachers supporting L1 use and the rest against it. This finding also aligns with the divide found in Question 21 of the teacher beliefs questionnaire. Similar reasons also emerged in the interviews with some having argued that L1 translations could help students comprehend science ideas whereas some having believed that an all-English environment was the most effective for preparing students for an English medium instruction university overseas and the use of L1 could undermine the students' motivation to communicate in English.

The main reason supporting L1 use was that during group discussion, students could get help from other students through L1 to explain what they did not understand in the teachers' input. Nicolas, a Biology teacher in School 5, provided a clear argument:

> '*The ultimate goal for an international program is that the students can talk about science and debate in English, but that does not happen. They always go back to Chinese. I think it is fine because if they can't express themselves correctly in English, what's the point of demanding it? They would just be sitting there and doing nothing.'*

Similarly, Kate also mentioned that she did not believe in total English immersion when the students' English proficiency is insufficient. She mentioned that *'if they are not getting it, it makes sense to let them use Chinese, so they understand the definition. What's the point of telling them a word if they don't understand it?'*

While some saw L1 as a tool for students to clarify concepts and communicate science ideas, a few teachers preferred an L2 only environment and considered L1 inhibition for their students' development of L2. They argued that an all-English immersion was the most effective for students' learning of English and that students should practice communicating science ideas in English, which prepares them for the English only environment in a university overseas. Louis's explanation provides a clear example – '*These guys will go to Canada. They are going to have to cooperate in the classroom in English and they are going ask their professor questions in English. Their professors will of course respond in English.'* Thus, it seems the factor of studying overseas was also a motivator for these teachers' support of L2 only, in addition to their view of L1 use as an obstacle for creating an English-only environment.

5.4.4 Difficulties of translation of beliefs into practice

While Sections 5.4.2 and 5.4.3 above presented the interview findings of teachers' beliefs about effective teaching of science and language in EMI science classes, this section presents the challenges that were mentioned by the teachers regarding translating their beliefs into practice in their EMI science classes with Chinese students. The main difficulties concerned the issues of using interaction and practical activities, and the teachers' struggle of understanding their students' language difficulties. These challenges can also provide crucial insights on what prohibited the teachers from implementing a constructivist teaching approach, which they clearly believed in, and creating favourable language learning conditions for their EMI students.

5.4.4.1) Difficulties with using interaction

As mentioned earlier, the value of interaction was clearly recognized for facilitating both science learning and language learning. However, difficulties were also mentioned by the teachers regarding translating their beliefs about interaction into practice in the EMI science classes in the foreign high school programs in China. The teachers often reported that they found it hard to elicit substantial output from students to talk about their science ideas, have their students interested in the process of solving problems through interaction, have students ask questions themselves, and understand students' group discussion in L1. Some of these difficulties were also reflected in the low level of classroom interaction and limited student output described in Chapter 4. The causes for these difficulties, as commented, included the students' limited English proficiency level, the passive culture of learning they were socialized into, and the monolingual teachers' inability of understanding the students' L1 during group discussion.

While the importance of students' output was recognized for both science and language learning, several teachers mentioned that they often found their students provided short answers without much depth and they often needed to probe more. This corresponds with the short average length of student turns, the limited use of verbs and teachers' frequent use of reformulation and repetition of questions observed in the lessons, as presented in Chapter 4. Some teachers mentioned that they typically received short and general answers with gestures from the students even in the recap or review stage of a chapter without substantiated explanations. A clear explanation was provided by Aaron, a Biology teacher at School 6:

> *'If I would ask what is enzyme? Sometimes I get like 'a protein'. Well yeah ok. But what is the feature of an enzyme? So, I feel like when I ask questions, I have to probe more deeply… Whereas I think with native English speakers, you know they may take from the book, but they will at least give me everything…'*

As to the reason for the limited output from the students, Aaron explained that it could be because of both the language difficulties and the depth of science understanding the students

had, but the main reason might still be the limited vocabulary. As he mentioned, even his higher performing students who had better science knowledge often still lagged behind in English proficiency. Other teachers considered the typical one-word short answers a reflection of the students' lack of interest in developing a thorough understanding of science concepts and the reasons behind scientific phenomenon.

Other teachers also mentioned that their students did not seem keen on being guided to discover answers through interaction. Several teachers commented that their students tended to learn through memorization. It was explained that the students often wanted to have the laws and formulas right away rather than working them out themselves and developing problem solving skills, which was regarded as the ultimate goal of learning science mentioned by several teachers, shown in Section 5.4.1.1 earlier. It was often mentioned that the students were used to listening and relying on rote memorization as a way of science learning. A typical explanation is from Johnson, a Biology teacher at School 7, that his students were comfortable with him lecturing but not so much with interaction:

> '*A student has told me that essentially they have to recite, a lot of recitation. That's why when I am lecturing the class, they are very comfortable. They are like lean back and I am ready to listen because they have been listening in their whole life.*'

Comments from other teachers also show that the culture of learning that the students were used to seemed to play a role in the challenges they experienced in using classroom interaction the way they intended to.

Similar to the findings above, several teachers specifically commented on how their use of questions was not well received by their students and the students did not seem comfortable with being questioned frequently. For example, Nicolas, a Biology teacher at School 5, mentioned that he would ask questions frequently in class, but he noticed that students often could not catch the questions and he needed to ask again, which echoes with the frequent use of reformulation and repetition of questions described in Chapter 4. As he explained, *'but the students may not be used to that and they would think, wait, I thought you were explaining something. I didn't hear the question. So, I have to re-say the question and get them re-focused*

on that.' He explained that the reason could be that the students could not differentiate the distinction between asking a question and providing a statement due to their lack of English proficiency, or that the students were not used to being asked to think about the content, which again, could be related to their habit of receiving knowledge and listening to teachers in classes.

The students' reluctance of asking questions themselves was also commented on. Some teachers explained that their students seemed to have been culturally socialized into a more passive learning style where speaking up was not encouraged. A typical quotation is from Mat, a Biology teacher at School 7:

> '*In China there seems to be the culture of not wanting to speak up in class. So, when they might not be getting it, they don't really want to put their hand up and admit it. So, it's more of a face thing.'*

Again, the role of the culture of learning was considered a reason for the students' lack of initiative in interacting with the teachers. The minimal number of student questions observed in the 30 lessons also provides evidence to the teachers' comments.

The difficulties of using group discussion were also often mentioned. Although the value of group discussion was consistently acknowledged by the teachers both in the beliefs questionnaire and in the interviews, some of the teachers mentioned they tended to use group discussion less with their Chinese students because the students often used Mandarin in group discussion. Some teachers commented they could not understand what their students were saying, and thus not being able to provide feedback. Another concern was that the teachers could not know whether the students were on task. Hence, it seems the monolingual teachers' inability of understanding the students' L1 lowered the willingness of some of them to use group discussion in their lessons.

In summary, the challenges of using interaction were commented to have stemmed from the language barriers their students faced, the culture of learning their students were used to, and the teachers' inability of understanding students' L1.

5.4.4.2) Difficulties with using practical activities

As mentioned in Section 5.4.1.4 earlier, some teachers' comments demonstrated a constructivist view of using practical activities and some comments reflected a more transmissionary view. Several major difficulties were mentioned by the teachers in their attempts of using practical activities in the way they wanted to, including the students' unease with analysing experiment data to form an explanation, the students' low English proficiency to understand and follow instructions, the limited time available for practical activities when the teaching of both science and English needed to be taken care of, and a lack of lab facilities in some schools.

While some teachers believed in the constructivist use of practical activities, they also commented that their students did not seem used to making sense of the experiment data and using the data to develop their own arguments. This seems to reveal a discrepancy between the way the students tended to use experiments in science learning and how the teachers believed experiments should be used. Chris, a Physics teacher at School 4, elaborated in length about how Chinese students may experience difficulties once going to study in the West particularly because of the experiment-based way science is taught there as compared to the memory-based method he found his Chinese students often relied on. As he mentioned:

> '*They learn it differently because it's more based on good memorization… In the west, students often need to write up the procedures and do their own experimentation. The averages are better here in China, but that's based on test-based numbers…What's more important is what happens to students after they finish school and when they are doing research.'*

Another difficulty mentioned was the language barrier for students to understand instructions accurately and the concern over safely because of that. Some teachers commented that due to the difficulties for their students to accurately understand the instruction in the labs, they used practical activities less. The limited time available for conducting experiments was also often commented on as the teaching of language took time away from classes. For example, Nicolas,

a Biology teacher at School 6, mentioned that he would use fewer lab activities with the Chinese students because the teaching of the language already took time away from the teaching of science and extra time was also needed for the EMI students to process input and respond through an L2 in classes, which left less time for lab activities. In addition, several teachers also mentioned the access to lab and availability of it also deterred them from using lab.

5.4.4.3) Teachers' understanding of the students' language difficulties

As mentioned earlier in Section 5.4.2.4, several teachers mentioned that their students had solid background knowledge about science and the main challenge lay in the language aspect. The language barrier was also considered a main reason for the difficulties the teachers faced in using interaction and practical activities. The teachers perceived three major language areas that are difficult for their EMI students - technical vocabulary, i.e., science terminologies, non-technical vocabulary, such as everyday vocabulary, and grammar. A stricter screening process during the admission process was also suggested to control for students' English proficiency.

Regarding the students' difficulty with technical vocabulary in English, some teachers mentioned that their students had strong Maths skills but were sometimes confused by certain technical vocabulary which may sound very difficult, but the actual idea could be very easy to them, such as '*stoichiometric point*'. A few teachers also realized that non-technical everyday vocabulary could cause problems as well in students' comprehension of a word problem. For example, Lennon, a Physics teacher at School 3, commented that *'...but even like more simple words, like swings, might come up in a word problem that are easy for Canadian students. But because we won't use them in normal classroom settings, they won't necessarily know it'.* The problem with non-technical vocabulary was also commented on in Section 5.4.1.2) Strategies for facilitating interaction in EMI classesand Section 5.4.2.1) The role of interaction. Another example of how non-technical vocabulary could cause problems was given by Johnson on how a different meaning of an everyday word '*fine*' in the phrase '*fine wires*' was confusing to his EMI students - '*we were talking about fine wires, so like most English speakers will know what fine means here. But some students may think it is the same as the 'fine' in 'how*

are you? I'm fine'. This example illustrates the difficulty of detecting the accurate meaning of polysemous vocabulary depending on the context, which would normally cause no trouble for L1 students.

The comments above about students' difficulties with non-technical vocabulary reflect some teachers' clear awareness of how their EMI students' struggle with language expanded to general non-science specific vocabulary apart from the technical terms. However, this theme was not mentioned by all teachers. This finding from the teachers' interviews complements with the finding from the teacher beliefs questionnaire where only seven teachers acknowledged general English was a problem for their EMI students in the subscale *Teachers' knowledge about EMI students' language difficulties*. The qualitative and quantitative findings together reveal a divide in the teachers' views where some teachers had clear awareness on this issue, and some did not.

Regarding understanding the students' language difficulties, several teachers also reported their own struggle with predicting which vocabulary items would potentially cause problems for their Chinese EMI students, particularly the non-technical vocabulary. As described by some teachers, most of the non-technical vocabulary they used would be familiar to L1 students and as there were so many non-technical words, it was difficult for them to predict which ones would be difficult and explain all of them. As a solution, some teachers mentioned they encouraged students to ask when they saw a new word they did not know.

Other language challenges included that students may know certain vocabulary but could not use them correctly in a sentence. It was mentioned that some students could provide a correct answer in a multiple-choice question but could not explain their ideas clearly in a short-answer question. These difficulties reflect that the students may lack necessary syntax knowledge to compose complete sentences correctly. Although these answers from the teachers reveal their awareness of the problem with grammar their students might face, they did not specifically mention the word 'grammar', 'sentence structure' or 'syntax'. This may suggest the teachers' lack of linguistic knowledge to dissect the language areas, which could also help to explain the findings from the teacher beliefs questionnaire where only about half of the teachers agreed it was important to teach grammatical structures commonly used in science texts. However,

another explanation is that some teachers did not regard the explicit teaching of grammar their duty in their science classes, as explained earlier.

Several teachers commented the students' lack of English proficiency a significant issue and called for a stricter admission process to admit only students with a certain level of English. As explained in Chapter 3 Methodology, there was a range of levels of students' English proficiency and academic performance in the sample. For example, the students in School 1 were considered to have a rather low level of English proficiency and academic performance and all the three teachers at School 1 (i.e., Colin, Kate and Emma) expressed particularly strong worries about their students' lack of necessary English skills. Colin mentioned that his students' lack of English proficiency seriously inhibited their participation in class and their academic progress. He explained that -*'it's discouraging for the students and for the teachers. And you know to be faced that monumental task of achieving of something meaningful with students in a course whose language skills are just so inhibiting for them.'* As he summarises, '*you've got to make sure that the students have at least a minimum amount of the language skills, given the level they need, to be able to actively participate in their own education.'*

5.4.5 The influence of Chinese medium instruction (CMI) science classes and the grade level on classroom interaction

As explained earlier, in most of the high school programs of this study the students spent most part of their days attending the foreign high school curriculum and a small part of their days attending the Chinese high school curriculum, which was usually run in the late afternoons and was all conducted through Chinese. The students typically attended the CMI classes in the first one or two years of their high school to obtain the Chinese high school diploma. The possible impact of the CMI science classes on the classroom interaction in the EMI science classes observed was enquired about in the teacher interviews. The possible impact of the grade level on classroom interaction was also enquired about to understand if the classroom interaction behaviour observed reflected only the pattern specific to a certain grade level.

5.4.5.1) The influence of CMI science classes on classroom interaction

In the post-lesson interviews and the general teacher interviews, the teachers were asked to comment on how much of the class observed they suspected was already known to the students through the CMI science classes they took. Most teachers commented that the knowledge taught in the EMI classes observed was new to their students or only certain basics were believed to have been taught in the CMI science classes. Some mentioned that the depth of knowledge taught in the EMI classes was often beyond what the students learnt in the CMI science classes. Thus, there seemed to be still a fair amount of new knowledge to learn in the EMI science classes.

Regarding how the CMI science classes may have influenced the classroom interaction in their EMI science classes, a few teachers mentioned when the students already knew certain basics of the topics learnt through their L1, this increased their students' confidence in speaking up and using the English language to describe something they already know. A typical quotation is from George - '*it makes it a bit easier if they are aware of what I'm teaching, like they've seen that before, like they are just getting like another point of view of the material. So that makes it much easier to comprehend.'*

The findings show that in most cases the EMI classes observed still took place in the situation where students were learning new content knowledge through English, i.e., an authentic EMI context rather than a language focused context where the students were learning how to describe known knowledge in an L2. The students' perspective on this issue was also enquired about in post-lesson interviews with students, which will be presented in the next chapter.

5.4.5.2) The influence of grade level on classroom interaction

Regarding the influence of the grade level on classroom interaction, the teachers' comments suggest that it was more difficult to have classroom interaction in Grade 10 classes due to their

lower English proficiency and unease with the learning environment in the foreign programs whereas Grade 12 students were found to be much more confident with using English to interact with the teacher and with other students.

Several teachers specified that the higher grade level students possessed a higher level of English and it was easier to use more teacher-student interaction, as well as student-student interaction. A typical explanation is from Hannah:

> '*With Grade 11 students, their English language is much higher than they were in Grade 10. So, I do more discussions, I get them to talk to each other more. Grade 10 students are very hesitant to use their English. They don't have the confidence yet. So, I don't expect as much from the 10th.'*

Other teachers also mentioned that Grade 10 students might experience more difficulties because they were new to the foreign program and needed to adjust to the learning environment, which requires interacting with teachers frequently. As described by Jenny, '*Grade 10 students are a bit scared to interact with teachers.*' A few teachers also mentioned that with lower grade students they had to particularly modify their input through speaking slowly and using simple vocabulary and so on.

In the lesson sample, eight lessons were from Grade 10, 18 lessons from Grade 11, and only four from Grade 12. Thus, the sample of lessons in this study may reflect more of the struggles of lower grade students, as described by the teachers above. It was also noticed that the difficulty level of the subject content knowledge across the grade levels was not mentioned in the teacher interviews as a factor. It was speculated that perhaps most of the teachers considered their students' English proficiency level the main factor in determining the classroom interaction behaviour. As mentioned earlier, several teachers described that their Chinese students tended to have solid science background knowledge but lagged behind in English. Thus, the findings here suggest again that the language aspect was considered by the

teachers as a more significant demand for their Chinese students than the science content knowledge.

5.4.6 Summary of the interview findings

The interview findings complemented the questionnaire findings in the sense that the interviews often provided explanations of the choices in the questionnaire, and the interviews also revealed issues which are important in understanding the teachers' beliefs but were not covered in the teacher beliefs questionnaire. These issues include the teachers' perceived importance of making abstract ideas concrete, teachers' use of input modification strategies and vocabulary teaching strategies, the incorporation of the language aspect in assessments and so on.

A clear commitment to the constructivist teaching approach of science was demonstrated in the interviews, with clear acknowledgement of the value of interaction. Teachers' comments about the roles of teacher-student interaction, student output, and teacher questions coincide with the clear constructivist belief shown in Section 1 of the teacher beliefs questionnaire. The interaction strategies mentioned particularly for EMI contexts also demonstrate the teachers' awareness of the help EMI students need for comprehending input and producing output in English.

The role of interaction for language learning was also acknowledged. A range of input modification strategies was mentioned but less attention was paid to providing corrective feedback to students' erroneous output. Explicit teaching of vocabulary emerged as the main language teaching strategy that was commented on, together with the evaluation of students' comprehension of English and production of English in assessments.

A division of opinions was observed in the use of practical activities and L1 use. Both constructivist use and transmissionary use of practical activities were mentioned. Support for

L1 use was shown among some teachers who worried that interaction and communication of science ideas would be compromised if L1 was not allowed. However, several teachers believed that all-English immersion was the most effective approach for enhancing students' English, without showing direct concern over the difficulty students may experience in learning science in an English-only environment.

The difficulties the teachers experienced in translating their constructivist beliefs into practice mainly stemmed from the students' low English proficiency and the culture of learning they were perceived to be used to. Students' difficulties with explaining ideas in lengths in English, a lack of skills in analysing experiment data, and a tendency of relying on teachers' lecturing rather than interaction were the typical difficulties the teachers reported.

5.5 Summary of the chapter

This chapter first presented the results from the teacher beliefs questionnaire and then the findings from the teacher interviews. The results from these two sources complement each other in providing a comprehensive picture of the teachers' beliefs about effective science teaching and English teaching in EMI science classes.

The teachers overall held a clear constructivist view of teaching science and acknowledged the important role of interaction for science learning. Most of them recognized ample teacher-student interaction and student-student interaction as vital components in science learning. Most teachers also demonstrated the understanding of the importance of knowing students' ideas and difficulties, checking students' previous knowledge, and using questions to guide students to realize their conceptual gap and guide their thinking. The value of interaction was also commented as amplified in the EMI context because of the significant need to check students' comprehension (e.g., the key vocabulary) and push them to speak up and describe science in English.

Similarly, favourable beliefs about language development were also demonstrated, with clear recognition of the importance of interaction for language learning. The teachers particularly acknowledged the need of sufficient exposure of input and having students produce output. What was commented on the most in the interviews is the variety of strategies for modifying input to make it comprehensible. However, the importance of providing corrective feedback to students' language errors and the role of students' lengthy output were acknowledged to a lesser degree.

The teachers clearly acknowledged the need to know about Chinese students' language difficulties and significant concern was shown over the language issue. A stronger worry about the Chinese students' language needs was shown, as compared to the learning of the science content. While some teachers specified the Chinese students' unease with critical thinking and use of practical activities to explain data scientifically, many also commented that their Chinese students had a solid basis of science and maths knowledge. It was rather consistently acknowledged that the main challenge for the students lay in the language aspect. A need for schools to set up stricter screening process regarding the students' English proficiency during admission was also expressed.

While the students' limited English proficiency was a consistent concern among the teachers, when it comes to specific areas of language, different degrees of attention were shown. Vocabulary received the strongest and most consistent attention, particularly technical vocabulary. Regarding the non-technical vocabulary, some teachers demonstrated clear awareness of the challenge they could cause, as elaborated in the interviews. However, some teachers did not seem to recognize it as a problem as shown by the belief questionnaire findings. The importance of explicit instruction on grammar also received less unanimous recognition. Facing the students' low level of English, the teachers overall also only showed a limited degree of identification of themselves as language teachers.

Regarding the use of L1, a division of views was observed among the teachers. Some teachers highlighted that L1 should be allowed in group discussion for students to freely exchange ideas and L1 could be used for explaining difficult concepts. Others showed a strong belief of an all-English immersion environment.

Difficulties for translation of beliefs into practice were also mentioned. Main difficulties included students' limited English, the culture of learning the students were socialized into, and the barrier of L1 the monolingual teachers faced in understanding the students' group discussion.

Monolingual teachers' interaction with Chinese students in English as the Medium of Instruction (EMI) science classes: an exploratory study of the foreign high school programs in China

Jiangshan An

Department of Education
University of Oxford
St Antony's College



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Supervisors
Professor Ernesto Macaro, Dr Ann Childs

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Chapter 6 Results of Students' Beliefs about Learning Science through English

This chapter presents findings about the students' beliefs about effective science learning and English learning in EMI science classes, answering the following research question:

Research Question 3: What are Chinese students' beliefs about learning science through English only, particularly about the role of interaction, in EMI science classes taught by monolingual teachers?

In this chapter, results from the student beliefs questionnaires will be presented first, followed by the findings of the post-lesson student interviews. As explained in Section 3.2.3.4 in Chapter 3 Methodology, the sample for student beliefs questionnaires includes two groups. Only findings from Group 1, the students in the observed and recorded lessons, are discussed here. The findings from Group 2, the students not in the observed and recorded lessons, were also consulted and presented in the tables for multiple-choice questions, as a reference to infer the degree to which the findings from Group 1 represent the target student population. The results from Group 2 will only be discussed if there is a dramatic difference between the two groups.

6.1 Students' motivation for attending

In Section 2 of the student beliefs questionnaire, students' reasons for attending a foreign high school program were investigated. The top reasons the students gave are that it prepares them for attending universities overseas and allows them to experience a different style of teaching that schools overseas often take, which, as some students explained, is more liberal and encourages more critical and individualized thinking. The concern for learning English was also often mentioned. Many students commented that attending a foreign program could improve their English and help them get used to an all-English environment. Finally, it was also frequently mentioned that going to a foreign high school program allowed them to avoid the competition in local high schools.

A contrast was found between students' desire for a learning environment where critical thinking is fostered and their limited commitment to a constructivist teaching approach, as shown in the student beliefs questionnaire and interviews. Similarly, the teachers also commented in the interviews that their students were more comfortable with note-taking, listening and memorization. These findings present a gap between what the students hoped for in attending a foreign high school program and what they actually believed to be effective teaching and learning in their EMI science classes.

6.2 Students' experience with learning science through English and monolingual teachers

This section presents findings of Section 3 of the student beliefs questionnaire on students' experience with EMI science classes and monolingual teachers. There is no equivalent section in the teacher beliefs questionnaire. The teachers' experience with Chinese students were enquired about in the general teacher interview.

6.2.1 Multiple-choice questions 1-5

The descriptive statistics of the multiple-choice questions are in Table 46 below.

Questions	**Students observed** (n=209)				**Student not observed** (n=93)			
	Mean answer (SD)	Distribution			Mean answer (SD)	Distribution		
		Strongly disagree/disagree	neutral	Strongly agree/agree		Strongly disagree/disagree	neutral	Strongly agree/agree
1). I very often don't understand the teacher in science classes.	2.1 (0.9)	65.6%	29.7%	5.7%	2.1 (0.9)	73.1%	20.4%	6.5%
2). In science classes, sometimes I know the answers to teachers' questions, but I don't answer because I am afraid of speaking in English.	2.4 (1.0)	55.5%	29.7%	15.3%	2.6 (1.1)	43.0%	36.6%	20.4%
3). In science classes, sometimes I know the answers to teachers' questions, but I don't answer because I don't know how to phrase it in English.	2.7 (1.0)	43.1%	32.5%	25.4%	2.9 (1.2)	39.8%	24.7%	35.5%
4). I think learning science through English has not really helped my English.	2.0 (1.0)	76.6%	15.3%	8.6%	2.2 (1.1)	67.7%	21.5%	10.8%
5). I like English more than before I started learning science through English.	3.1 (1.0)	23.9%	45.5%	31.6%	2.9 (1.1)	31.2%	44.1%	24.7%

(1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

Table 46 descriptive statistics of Section 3 of student beliefs questionnaire

Students' answers to Item 1 suggest most students understood their foreign teachers in their EMI science classes. Item 2 and Item 3 showed students' limited identification of the fear of speaking in English and a lack of English proficiency as reasons for not participating in classroom interaction. Only 15.3% of the students recognized the former and only 25.4% recognized the latter.

Regarding Item 4, most students felt learning science through English helped their English. As to Item 5, only a small proportion, 31.6%, of the students agreed that they liked English more after receiving EMI science classes and about half of the students were neutral. This shows that while most students perceived EMI science classes helpful for learning English, they did feel they liked English more because of the EMI science classes.

The students not in the observed and recorded lessons also showed a similar spread of views for all the five questions. This suggests the results from Group 1 reasonably reflected the target student population.

6.2.2 Open-ended question 6

Regarding Question 6a. *Do you think English has caused any trouble in your science learning*, among the students who participated in lesson observations, 130 (62%) students chose 'yes' and 80 (38%) students chose 'no'. This shows that most of the students felt that English caused trouble for science learning. A similar proportion was also found with the students not in the observed and recorded lessons, with 68% students having chosen 'yes' and 32% students having chosen 'no'. Thus, although the finding of the multiple-choice Question 1, as shown above, suggests that most students could understand their teachers in their EMI science classes, a large proportion of the students still admitted that English caused trouble in their science learning.

The most commonly mentioned challenge in students' explanations is the high quantity of subject-specific terminology, i.e., technical vocabulary, as termed in Section 2.3.4.4.2.2 The difficulties EMI science students experience, which significantly inhibited students' comprehension of the lessons, textbooks and questions in tests. Some students further explained that even though sometimes the actual calculations could be easy, the technical vocabulary inhibited their accurate understanding of the questions and thus they were not able to answer questions correctly. It was also mentioned that sometimes it was still hard to make sense of phrases and sentences even when they knew the Chinese meaning of the new technical vocabulary contained in these phrase and sentences. This reflects the students' possible lack of knowledge about English grammar. Or, it could also be that the science knowledge represented at the science level was perceived difficult by the students.

Another commonly mentioned theme is the difficulty for constructing lengthy answers in English and accurate phrasing of questions in lessons. These challenges students reported experiencing are also reflected in the teachers' answers in the interviews, as explained in Chapter 5. Similarly, it is interpreted here that this difficulty of constructing lengthy answers and accurately phrasing questions could be a result of the students' lack of grammar knowledge, which will be elaborated on in Chapter 7 Discussion and Conclusion.

Question 6b enquires about students' strategies for solving these problems. The common themes from students' answers include expanding vocabulary repertoire through memorizing more words, looking up new words and writing down the Chinese meaning before, during and after lessons, making connections with what was learnt before in Chinese, and asking teachers and peers for help. The reliance on Chinese stood out as a main coping strategy. These explanations could help to explain the finding of the multiple-choice Question 1 above, where the majority of the students did not regard understanding their teachers in science classes difficult. The reason could be that, with the help of Chinese translations and the preparation of looking up the new words, the students did not find it particularly hard to understand their science teachers in class.

The reported significant pressure and challenges due to the great number of new technical vocabulary is in line with the findings from the teachers' beliefs questionnaires and the interviews, presented in Chapter 5, where vocabulary was also commented a main challenge. However, an initial discrepancy emerged between the teachers' strategies and the students' strategies reported to deal with this issue. While the students considered L1 as a key strategy, some teachers disapproved the use of Chinese and reported the use of other strategies such as breaking down vocabulary, using simple words and repetitions, having vocabulary quizzes and so on to address the language difficulty. More findings about the students' strategies regarding the language challenges are presented later in Section 6.5.3 of this chapter.

Similar themes also emerged in the answers from the second group of students regarding the troubles English caused and their strategies to deal with them. This shows that the answers from the students who were in the observed and recorded lessons to a reasonable degree represent the common experiences of the target student population.

6.2.3 Open-ended questions 7&8

Regarding Question 7, 43.5% students chose option a, a bilingual science teacher, and 33.8% chose option d, a monolingual science teacher but a bilingual teaching assistant. Only 8% and 15% students chose option c and option d respectively. This shows a clear desire from the students for having ample exposure to English but also the option of using their L1 to communicate with the teacher. Thus, the students' view is in contrast with the teachers' answers

to this same question in the teachers' beliefs questionnaire, Question 22 in Section 2, where 53% of the teachers chose option c, i.e., a native-English speaking monolingual teacher who cannot speak Mandarin.

Students' answers to the open-ended Question 8 provide explanations about their attitude towards the monolingual science teachers. Although many students wrote having a monolingual teacher could expose them to authentic English and help them reduce reliance on Chinese, they also at the same time noted that no use of Mandarin also reduced the opportunities of communication with their teachers. As they frequently mentioned, the use of only L2 deterred them from asking teachers questions and explaining their own ideas to their teachers.

A look at the answers given by students not in the observed and recorded lessons also yields similar main themes. This suggests the answers given by the students who participated in the lesson observations of this study are to a degree be common among the target student population.

6.3 Students' beliefs about effective science learning

This section presents findings of Section 4 of student beliefs questionnaire on beliefs about science learning. This section corresponds with Section 1 of teacher beliefs questionnaire.

6.3.1 Multiple-choice questions 1-16

The overall mean score for this section is 3.6 out of 5, with a standard deviation (SD) of 0.8. This shows an overall mildly constructivist stance towards the learning of science and a limited spread of opinions. Table 47 below shows the mean answer and SD of each question item and the mean score and SD of each subscale.

Item	**Students observed Mean answer (SD) n=**			**Students not observed Mean (SD) answer n=**		
	Strongly disagree/disagree	neutral	Strongly agree/agree	Strongly disagree/disagree	neutral	Strongly agree/agree
Subscale 1: Role of previous knowledge (Mean score: 3.6, SD=0.9)						
2.When introducing a new topic, asking students about their existing knowledge about the topic is **NOT** necessary.	2.1 (0.9) n=215			2.1 (0.9) n=114		
	68.4%	27.9%	3.7%	67.5%	27.2%	5.3%
5.Students have difficulties learning scientific concepts mainly because their ideas about how the world works are often resistant to change.	2.8 (1.0) n=216			3.1 (1.1) n=113		
	34.7%	43.5%	21.8%	31.0%	33.6%	35.4 %
6.When teaching a new topic, making reference to students' preconceptions is **NOT** necessary.	2.1 (1.0) n=215			2.1 (1.0) n=114		
	69.3%	24.7%	6.0%	69.3%	21.1%	9.6%
11.Teachers should **NOT** let students' existing understandings, or their difficulties determine the direction and the focus of lessons.	2.0 (0.8) n=215			2.2 (1.0) n=114		
	79.1%	15.8%	5.1%	64.0%	28.1%	7.9%
15.Telling students' new knowledge upfront is more effective than helping students construct their own understanding based on their existing knowledge.	2.4 (1.0) n=212			2.5 (1.0) n=104		
	58.0%	29.2%	12.7%	52.9%	27.9%	19.2 %
Subscale 2: Role of practical activities (Mean score: 2.9, SD:0.9)						
7. Students should explore and conduct their own experiments with hands-on materials before the teacher discusses any new scientific concepts with them.	3.4 (0.9) n=215			3.4 (1.1) n=113		
	11.6%	42.8%	45.6%	15.9%	36.3%	47.8 %
	3.6 (1.0) n=214			3.5 (1.0) n=114		

9. Experiments should be included in lessons as a way to reinforce the scientific concepts students have learned in class.	10.3%	33.2%	56.5%	14.0%	33.3%	52.6 %
Subscale 3: Role of interaction: students' output (Mean score: 3.6, SD:0.9)						
8. In most classes, students' substantial verbal explanations of their ideas are **NOT** necessary. Having short verbal answers from students is good enough.	2.3 (1.0) n=210			2.2 (1.0) n=113		
	59.5%	30.5%	10.0%	65.5%	23.0%	11.5 %
10. In most situations, teachers should do most of the talking in class.	3.0 (0.9) n=214			3.1 (0.9) n=114		
	28.5%	44.9%	26.6%	20.2%	46.5%	33.3 %
13. Teachers' elicitations of substantial verbal answers from students to explain our views are **NOT** necessary for my learning.	1.9 (0.9) n=214			2.0 (1.0) n=114		
	79.4%	14.0%	6.5%	74.6%	16.7%	8.8%
Subscale 4: Teacher-student interaction vs teacher monologues (Mean score: 3.5, SD: 0.8)						
1.Interaction between teacher and students is important for learning science.	4.0 (0.9) n=216			4.0 (0.8) n=114		
	5.6%	20.4%	74.1%	1.8%	28.1%	70.2 %
3.In most situations, teacher's monologue of explanation is more effective and helpful for my science learning than teacher-student interaction.	3.0 (0.9) n=215			3.1 (0.9) n=114		
	25.1%	***53.5%***	21.4%	24.6%	48.2%	27.2 %
Subscale 5: Student-student interaction (Mean score: 3.9, SD=0.8)						
4.It is **NOT** useful for us to discuss and debate multiple possible answers with each other in class.	2.1 (1.2) n=215			2.1 (0.9) n=114		
	74.0%	19.5%	6.5%	71.9%	20.2%	7.9%
12.Interaction between students and students is **NOT** important for learning science.	2.1 (0.9) n=215			2.1 (0.9) n=112		
	69.8%	24.2%	6.0%	72.3%	20.5%	7.1%
Subscale 6: The role of teacher questions (Mean score: 3.6, SD=0.7)						
14. Most of the questions in my science classes should be about asking us to recall information.	2.7 (0.8) n=215			2.8 (0.9) n=114		
	38.6%	48.4%	13.0%	33.3%	50.0%	16.7 %
16. Teachers' questions that require us to compare and identify relationships between concepts are **NOT** necessary.	2.2 (0.8) n=211			2.0 (0.8) n=114		
	68.7%	26.5%	4.7%	74.0%	24.0%	1.9%

(1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

Table 47 Descriptive statistics of Section 4 of student beliefs questionnaire

Subscale 1 shows that most students recognized the importance for their teachers to understand and make references to their prior knowledge and adjust teaching based on students' existing knowledge, as shown in Items 2, 6, and 11. However, a less constructivist view was shown in

Items 5 and 15. In Item 5, only 21.8% of the students recognized existing perceptions cause major challenges in learning new science knowledge. Item 15 shows that only 58.8% of the students believed in the value of constructing knowledge with the teacher based on their existing knowledge, as compared to listening to the teacher telling them new knowledge upfront. Thus, the students held a less constructivist idea when it comes the students' own responsibility of challenging their prior perceptions and constructing new knowledge based on existing understandings.

Subscale 2 shows that many students believed in both transmissionary use of practical activities and the constructivist use of them, and many were neutral. Item 7 shows that 45.6% of the students agreed with the constructivist approach of conducting experiments. Similarly, Item 9 saw about half of the students, 56.5%, acknowledged the transmissionary use of practical activities, i.e., using experiments as reinforcement of knowledge learnt. For both items, a sizable proportion of the students were neutral. The findings overall reflect that the students did not seem to have a clear stance on the role of practical activities.

Subscale 3 on students' output shows that despite a general constructivist belief about teachers' making an effort to elicit lengthy answers from students, the students showed a less constructivist belief when short answers were provided as an option. Item 8, with the option of short answers, only 59.5% of the students acknowledged substantial answers are necessary, as compared to 79.4% in Item 13. Similarly, Item 10 also shows as little as 28.5% of the students disagreed that the teachers should do most of the talking in most situations.

Subscale 4, similar to Subscale 3, also revealed the students' general recognition of the importance of teacher-student interaction, but less recognition was shown when it comes to comparison with listening to teacher monologues. 74.1% of the students acknowledged teacher-student interaction is important in Item 1 but only 25.1% of the students remained holding a constructivist view in Item 3 when teacher's monologue of explanations is provided as an option.

Subscale 5 has the highest mean score among all subscales, i.e., 3.9, showing that the strongest constructivist belief held by the students was on the issue of student-student interaction. A clear majority of 74.0% and 69.8% was shown in both Items 4 and 12, recognizing the importance of discussing multiple perspectives among students themselves.

Subscale 6 showed students' constructivist views about higher-order thinking questions from teachers but less constructivist views on recall questions. In Item 16, a majority of 68.7% of the students believed in the value of higher-order thinking questions from teachers. However, in Item 14 only 38.6% of the students clearly believed recall questions should not be the majority of teacher questions, with 48.4% being neutral.

6.3.2 Open-ended questions 17&18

Students' answers to Question 17a show a variety of methods students believed are effective for their science learning. The most frequently mentioned ones include doing ample amounts of practice questions and past exam papers to consolidate new knowledge, doing previews and revisions after class, asking questions and communicating with teachers, and having discussion with peers.

Regarding Question 18a, which enquires specifically about effective ways of learning science through English, many students stated that the same methods mentioned for Question 17a also applied here. Attention to the language aspect was also frequently mentioned, such as looking up new words before lessons and previewing the science knowledge through L1 first. These answers reveal, again, students' reliance on L1.

Students' answers to Question 17b and Question 18b showed acknowledgement of the value of interaction for science learning. In Question 17b, the students mentioned that interaction with

teachers allows teachers to find out students' misunderstandings and problems so more targeted teaching can be provided. Interaction was also commented as helpful to develop a more thorough understanding of science knowledge, deepen students' memory of knowledge, promote more thinking, and help students realize the problems in their thinking.

A small number of students displayed a more transmissionary view of the role of interaction for science learning. The main answers are that teacher-student interaction takes too much time and limits how much science content can be taught in a lesson, and that learning science is mostly about your own understandings of laws, formulas and calculations. Some students also mentioned that they preferred listening in class and if there are questions, and they prefer asking peers or sorting them out by themselves. These answers suggest that some students did not realize the value of interaction for learning science. This finding coincides with the limited level of constructivist view shown in multiple-choice Items 3, 10 and 15 in Section 4 of the questionnaire, where a sizable proportion of the students had a neutral view of teachers' doing most of the talk in lessons and telling students new knowledge upfront.

The common answers for Question 18b showed students' belief about how interaction could help their language learning in EMI science classes. It was frequently mentioned that interaction could enhance comprehension, allow practice of speaking, and help understanding of how to use science-specific language. Some students also commented on the heightened importance of interaction for the EMI context because they were learning science through a second language and thus it was more important for teachers know their misconception.

6.3.3 Summary of the students' beliefs about science learning

Overall a weak tendency towards the constructivist view was demonstrated across all the sub-scales of the multiple-choice questions. The students demonstrated a clear constructivist view regarding the general value of teacher-student interaction, teachers' questions to elicit substantial output from students, the importance of letting teachers understand their existing understandings, as well as the role of high-order thinking questions. However, the students' constructivist view became less firm when being presented with the option of a more transmissionary approach, such as having teachers do most of the talk, listening to teachers' monologues, having teachers tell them new knowledge upfront, and teachers' use of recall questions as the main type of questions.

These findings suggest a sizable proportion of the students still were receptive of a more passive learning approach. This lack of thoroughness in the constructivist idea also to a degree coincides with the teachers' comments in the interviews. As mentioned in Chapter 5, the teachers described their students' tendency of relying on memorization and listening to teachers and their lack of interest in discovering solutions through interaction.

Students' strong reliance on Chinese also emerged. Looking up new words in Chinese before lessons turned out to be a common method that students used. This finding also reinforces the themes that emerged from Questions 6 and 7 in Section 3 of the student questionnaire, where reliance on Chinese was mentioned as a key strategy to cope with the large quantity of new technical vocabulary.

As shown in the tables of this section, the answers from the students who were not in the observed and recorded lessons are very much in line with the students who were. This alignment shows that the answers from the students who were in the observed and recorded lessons could to a reasonable degree represent the beliefs in the target student population.

6.4 Students' beliefs about effective language learning in EMI science classes

This section presents the results of Section 5 of the student beliefs questionnaire.

6.4.1 Multiple-choice questions 1-20

The overall mean score of the multiple-choice questions in Section 5 is 3.6, with a standard deviation of 0.9. This suggests an overall mildly favourable view for English language learning in EMI classes, with a fairly small range of variation among the students. The descriptive statistics of the answers to each items are shown in Table 48 below, together with the mean score and SD of each subscale.

Item	**Students observed Mean answer (SD) n=**			**Students not observed Mean answer (SD) n=**		
	Strongly disagree /disagree	neutral	Strongly agree/ agree	Strongly disagree /disagree	neutral	Strongly agree/ agree
Subscale 1: Teachers' proficiency of the language of science (Mean score: 3.4, SD: 0.8)						
19.My EMI science teachers need to have better proficiency of using the language of science (i.e., the specific way of using language to talk about science).	3.4 (0.8) n=210			3.5 (0.8) n=98		
	12.4%	44.3%	43.3%	7.1%	45.9%	46.9%
Subscale 2: Teachers' knowledge about the English language and attitudes towards it (Mean score: 3.7, SD: 0.8)						
14. My EMI science teachers do **NOT** need to have knowledge about English grammar.	2.0 (0.9) n=210			2.0 (0.9) n=99		
	77.1%	16.7%	6.2%	69.7%	23.2%	7.1%
16. My EMI science teachers do **NOT** need to know about the way English is pronounced.	1.9 (0.9) n=210			1.9 (0.9) n=99		
	78.1%	15.2%	6.7%	74.7%	19.2%	6.1%
18. My EMI science teachers have good explicit knowledge about the way English language works.	3.5 (0.9) n=209			3.4 (0.8) n=99		
	12.4%	37.8%	49.8%	10.1%	49.5%	40.4%
Subscale 3: EMI science students' language difficulties						
3.1 Students' recognition with the areas of language they need help with (Mean score: 3.3, SD:0.9)						
3.The language of science (i.e., the specific way of using language to talk about science) in English is **NOT** a problem for me.	2.9 (0.9) n=209			2.9 (1.0) n=103		
	35.9%	40.7%	23.4%	35.0%	42.7%	22.3%
4.The general use of English language (not science-specific language) is a problem for me in learning science through English.	2.4 (0.9) n=212			2.2 (1.0) n=106		
	56.1%	32.1%	11.8%	64.2%	25.5%	10.4%
	3.9 (0.9) n=212			3.9 (0.9) n=106		

8. It is helpful to have explanations of difficult words in textbooks or text-based notes from my science teachers.	8.0%	18.4%	73.6%	5.7%	21.7%	72.6%
9. It is **NOT** important for my science teachers to teach us the English grammatical structures commonly used in science texts (e.g. passive voice).	2.6 (1.0) n=210			2.7 (1.1) n=106		
	43.8%	39.5%	16.7%	45.3%	33.0%	21.7%
10. It is important for my science teachers to model ways of using English language to develop arguments in science.	3.8 (0.9) n=210			3.8 (0.9) n=104		
	7.1%	21.4%	71.4%	7.7%	21.2%	71.2%
3.2 Students' view on whether teachers should know about EMI students' language difficulties (Mean score: 3.7, SD:0.8)						
15. My EMI science teachers should have knowledge about my difficulties in learning English grammar.	3.6 (0.9) n=210			3.6 (0.9) n=99		
	11.0%	29.5%	59.5%	11.1%	33.3%	55.6%
17. My EMI science teachers should have knowledge about my difficulties in pronouncing English.	3.6 (0.8) n=209			3.6 (0.8) n=99		
	10.0%	31.6%	58.4%	5.1%	38.4%	56.6%
20. My EMI science teachers do **NOT** need to know about my difficulties in learning the language of science.	2.1 (0.9) n=201			2.0 (1.0) n=96		
	71.6%	21.9%	6.5%	66.7%	28.1%	5.2%
Subscale 4: EMI teachers' role as a language teacher (Mean score:3.7, SD=1.0)						
1.I need to focus on science in my science classes, **NOT** English language.	2.8 (1.0) n=210			2.8 (1.2) n=103		
	48.5%	23.3%	28.2%	48.5%	23.3%	28.2%
2.It is **NOT** my task to learn the academic language required for learning science in English (e.g., the English language used in writing a chemistry lab report, describing phenomenon etc.) in my EMI science classes.	1.9 (0.8) n=209			2.0 (1.0) n=103		
	80.4%	14.8%	4.8%	75.7%	16.5%	7.8%
Subscale 5: The role of interaction **(Mean score: 3.7, SD=0.9)**						
6. I hope my EMI science teachers would correct my oral English in EMI science classes to improve my English.	3.6 (1.0) n=212			3.4 (1.1) n=107		
	12.7%	30.7%	56.6%	22.4%	27.1%	50.5%
7. I hope my EMI science teachers would correct my written English in EMI science classes to improve my English.	3.7 (0.9) n=211			3.5 (1.1) n=105		
	8.1%	27.5%	64.5%	18.1%	25.7%	56.2%
11.1). Spoken English language output is unnecessary for me to improve my English.	1.9 (0.8) n=212			2.0 (1.1) n=105		
	76.1%	18.9%	5.0%	69.9%	22.3%	7.8%
11.2). Written English language output is unnecessary for me to improve my English.	1.9 (0.9) n=201			2.0 (1.1) n=103		
	76.1%	18.9%	5.0%	69.9%	22.3%	7.8%
12. In EMI science lessons, I do **NOT** need regular opportunities to talk about science in English.	2.4 (0.9) n=213			2.4 (0.9) n=106		
	59.2%	27.7%	13.1%	52.8%	38.7%	8.5%
	3.5 (0.9) n=211			3.6 (0.9) n=106		

13.1).Doing work in science that requires long spoken answers in English is helpful for me to improve my English.	11.4%	37.9%	50.7%	7.5%	42.5%	50.0%
13.2).Doing work in science that requires long written answers in English is helpful for me to improve my English.	3.3 (0.9) n=204			3.3 (0.9) n=93		
	11.4%	37.9%	50.7%	7.5%	42.5%	50.0%

(1=strongly disagree, 2=disagree, 3=neutral, 4=agree, 5=strongly agree)

Table 48 Descriptive statistics of Section 5 of student beliefs questionnaire

While the overall belief shown in this section is mildly favourable for language learning, several items reflect students' unfavourable views for English learning in EMI science classes. Item 19 in Subscale 1 showed 44.3% of the students chose *neutral* and 43.3% agreed or strongly agreed. This shows the majority of the students lacked confidence in their EMI science teachers' proficiency of the language of science. In Subscale 2, the majority of the students believed EMI science teachers should have knowledge about English grammar and pronunciation, but only 49.8% of the students believed their science teachers actually possess good knowledge about the English language, as shown in Item 18. Overall the students reported limited trust in their science teachers' mastery of the language of science and knowledge about English in general.

Subscale 3.1 revealed more unfavourable views about language learning in EMI science classes, with the lowest mean score, 3.3, of all subscales. In Items 3 and 4, only 35.9% of the students acknowledged that the language of science was a problem for them and only 11.8% perceived the use of general English a problem. The small proportion of 35.9% contrasts with the answers to the open-ended Question 6 in Section 3 of the questionnaire, presented earlier in Section 6.2.2 of this chapter. There the difficulties with technical vocabulary and clearly composing answers and questions about science ideas were widely mentioned. This raises the question as to whether the students understood the meaning of '*the language of science*' here.

The students also showed more concern for vocabulary teaching than grammar teaching. Items 8 and 9 in Subscale 3.1 show the students clearly hoped for teachers to explain difficult words, but only 43.8% believed the teaching of grammatical structures common in science context important. However, teachers' modelling of using English to construct arguments and ideas

about science was widely considered important, with 71.4% of the students agreeing. This indicates students' possible preference for implicit teaching of grammar rules rather than explicit teaching.

Subscale 3.2 shows primary concern for the learning of the language of science. 71.6% of the students believed their EMI science teachers should know about their difficulties with the language of science, but only a small majority believed the same with grammar and pronunciation. This contrasts with Item 3 in Subscale 3.1, and suggests that the students recognized the need for their teachers to understand their difficulties but might not be as clear and forthcoming in recognizing the problem they were experiencing themselves with the language of science.

Limited recognition of EMI teachers as language teachers was shown in Subscale 4. A clear contrast was found between Item 1, and Items 3 and 5. 80.4% of the students believed focusing on the academic language required in science learning was their task, but only a minority of the students believed so with English in general and supported having English learning goals included as part of lesson objectives.

Lastly, a mild level of recognition was shown to the role of interaction for language learning in Subscale 5. The hope for feedback was particularly low, with only a small majority of 56.6% and 64.5% hoped their teachers would correct their oral and written English in their EMI science classes. A sizable minority of the students were also neutral. The students were also found to be less inclined with recognizing the benefit of lengthy and regular output. A majority of 77.5% and 76.1% believed in the general role of output for English learning, shown in Items 11 (1) and 11 (2). In comparison, much fewer students, i.e., 50.7% and 38.2%, believed in the benefits of producing lengthy output, shown in Items 13 (1) and 13 (2). Similarly, fewer students acknowledged the benefit of regular output, shown in Item 12.

6.4.2 Open-ended question 21

A range of ideas about effective ways of learning English were mentioned in students' answers. A very small number of students explained that learning English was not one of their tasks in EMI science classes. The commonly mentioned effective ways include expanding vocabulary repertoire, communicating with teachers and peers more in English, including asking teachers' questions in English and describing ideas in English, looking up new words and memorizing them, particularly the technical vocabulary, and doing more practice questions that are in English.

These main themes suggest that, first of all, most students did acknowledge English learning as one of their tasks in the science classes. Frequent attention to how communication with teachers and peers improves English also shows their general acknowledgement of the crucial role of interaction for language learning. The looking up and memorizing of technical vocabulary, again, indicate the concern for new technical vocabulary and their reliance on having the Chinese equivalents.

In the students' answers, the role of substantial oral and written output was less frequently mentioned, and the role of corrective feedback was not mentioned at all. This relative lack of attention to these elements of interaction also echoes with the less degree of recognition showed for feedback and lengthy output in students' answers for Items 6, 7 on feedback and Questions 13 (1) and 13 (3) on substantial oral and written output earlier.

Based on the answers to the multiple-choice questions and the open-ended question, it seems while the students did not regard paying explicit and conscious attention to English learning as their task in science class, they did hope to improve their English learning in EMI science classes mostly through a more implicit and communicative approach of using English more. However, the academic English language related to science, particularly the technical vocabulary, was considered an area needing explicit and thorough effort.

6.4.3 Open-ended question 22

In response to Question 22, most students stated that they did not participate much in teacher-student interaction in class. As an alternative, many students explained that they tended to ask questions during self-practice time or relied on themselves for figuring out the science knowledge. Only a small number of students mentioned that they would actively try to participate in class. The main purpose was to practice their English, and to check if their understandings of science concepts are correct and to enhance their comprehension of science ideas.

The main reason for the lack of participation given by the students was their limited English proficiency to accurately explain science ideas. The language issues mentioned include limited vocabulary, not knowing how to pronounce certain vocabulary, a feeling of embarrassment about speaking English, a lack of knowledge about grammar to compose ideas clearly, a lack of comprehension of the teachers' utterances, and a concern for taking away the lesson time from teacher talk by asking questions. The theme of seeing asking questions as taking away lesson time for the teacher to teach content knowledge reinforced the tendency shown in the multiple-choice questions where some students were drawn to the idea of letting teachers doing most of the talk.

The recognition shown to a lack of English proficiency and the feeling of embarrassment also helps to clarify students' answers to multiple-choice Questions 2 and 3 in Section 3 of the questionnaire. While answering the multiple-choice questions, the students might not have thought about the answers as thoroughly, and thus did not recognize the issues of language difficulties and fear of speaking up. Further evidence can be found in student interviews, shown in Section 6.5 later.

The language issues mentioned here also provide clarifications of the multiple-choice Items 3 &4 of Section 5 of the questionnaire. Although the students did not explicitly mention the areas of the language of science and general English here, the language issues mentioned

demonstrated that both could be at play. For example, the lack of comprehension of teachers' utterances could be caused by the language of science used by the teachers, e.g., technical terms, and certain grammar structure used in the teachers' utterances, which could be general English. The difficulty of composing ideas clearly could also stem from a lack of knowledge about the grammar structures that are common to science discourse and general English grammar. These speculations can be verified in student interviews in Section 6.5 later.

The students' answers here show that, although they acknowledged the general value of interaction for language learning, a number of obstacles existed for them to actually engage in teacher-student interaction in EMI science classes through English only.

6.4.4 Summary of students' beliefs about learning English in EMI science classes

The students' beliefs overall demonstrated mildly favourable views for language learning. The students in general expected their science teachers to be capable of teaching grammar and pronunciation and know about their difficulties in these areas. However, they were not particularly confident with their teachers' knowledge about English. Similarly, the students expressed a clear desire that their science teachers need to know about their difficulties with the language of science but, again, they were also not particularly confident with their teachers' proficiency of the language of science. This low level of confidence the students had in the teachers may be reflective of an unfavourable condition for language learning in the EMI science classes.

Among the different areas of language, difficult vocabulary and the academic language of science and stood out as the areas that the students recognized as important to be addressed in EMI science classes. In comparison, less recognition was given to grammar and general English. However, a lack of knowledge about English grammar was in fact frequently mentioned as one difficulty to engage in communication with the monolingual science

teachers. Thus, an inconsistency emerged in that while the students did not consider the explicit teaching of grammar important, they clearly reported the lack of grammar knowledge as a difficulty in their communication with teachers. Similarly, while the students considered the general use of English not a problem for them, their general low English proficiency was also reported as a main reason for their lack of participation in classroom interaction. Thus, it is worth asking the question whether the general use of English, including the knowledge of grammar, actually plays an important role in effective communication with teachers in EMI science classes.

Regarding EMI teachers' role as language teachers, the emerging belief is that the students clearly hoped to learn the academic language required for learning science and had a general concern for their English learning in EMI science classes, but they seemed to opt for a more implicit and communicative approach through listening and speaking rather than having explicit instruction on English. Regarding the role of interaction, the students recognized that output is necessary for the learning of English, but their recognition became weaker when it comes to producing lengthy and substantial output.

In summary, a content-driven view regarding language learning was reflected through the students' strong focus on the language of science, technical vocabulary and an overall preference of learning English through communication without much explicit instruction reflects. It seems English language overall takes a secondary role and the language that is immediately and specifically related to the content concepts is more important to learn.

6.5 Findings from students' interviews

As explained in Chapter 3 Methodology, two students were interviewed together after each lesson observation to reflect on their learning in the lesson just observed. Findings from these

interviews also contributed to answering Research Question 3 on Chinese students' beliefs about learning science through English in EMI science classes taught by monolingual teachers.

In almost all the interviews with the students, they stated that the lesson observed was representative of the normal lessons and normal teacher-student interactional behaviour in their lessons. This means that the lesson observations, to a reasonable degree, reflect the ordinary teacher-student interaction behaviour in these EMI science teachers' classes. In most of the interviews, the students also stated that the science content was mostly new to them. This ensures that the teacher-student interaction observed in the lessons can reasonably reflect the behaviour in authentic EMI classes where new subject knowledge is taught through English rather than translating previously taught knowledge into English.

All the interviews were transcribed and coded based on the common themes. The qualitative analysis generated the following themes:

6.5.1) Challenges in learning science through English

6.5.1.1) Technical vocabulary

6.5.1.2) Everyday vocabulary

6.5.1.3) Interaction with teachers only through L2

6.5.2) Effective strategies used by the teacher or the students themselves for science learning

6.5.2.1). Doing practice questions

6.5.2.2) Teachers' use of visual aids (drawing, diagrams, pictures)

6.5.2.3) Asking teacher questions

6.5.3) Effective strategies used by the teacher or the students themselves for English learning

6.5.3.1) Reliance on Chinese

6.5.3.2) Teachers' use of vocabulary worksheet and explicit teaching of vocabulary

6.5.3.3) Other strategies

6.5.4) The influence of Chinese medium instruction (CMI) science classes on classroom interaction

In response to the question about challenges, many students mentioned the strategies they used, or their teachers used which they perceived as effective for their learning of science through English. These strategies are considered reflective of students' beliefs about science learning through English, and thus are considered worth reporting.

6.5.1 Challenges in learning science through English

Analysis of the post-lesson interviews showed that the biggest challenge reported by the students was the high quantity of technical vocabulary. Other challenges included certain everyday vocabulary that inhibited comprehension of science ideas, and the difficulty of interaction with the foreign teachers only through English.

6.5.1.1 Technical vocabulary

In almost all the post-lesson interviews, the students mentioned that the high quantity of technical vocabulary caused difficulties in their comprehension of the lessons. For example, one student in Christina's class mentioned that '*because of the density of these terms, you had to pay attention very closely all the time. If you miss a point, you will be lost*'. These comments also align with what was termed in Halliday & Martin's (1993) work as *lexical density* as a key feature of science texts.

Other students also mentioned that they could guess the meaning of new technical vocabulary, but it was hard to memorize them without sufficient help from the teachers. One student from Stella's class provided a clear example:

> '*Angiosperm, I don't know how to pronounce it. I know roughly the meaning. It is the most complex type of plants. It has flowers. All the terms look complicated, but we know roughly the meaning behind it. But it would be hard for us to memorize all these terms. The teacher usually does not provide much help in helping us comprehend the difficult biology specific vocabulary'.*

Here it can be seen that sometimes students could grasp some characteristics of the concept certain technical vocabulary represent, but they did not feel they were not able to develop a clear and thorough understanding of them and remember all of them. Pronunciation of some difficult terms, such as '*angiosperm*', was also reported to be an issue. As the student clearly pointed out, more targeted help from the teachers to facilitate comprehension of subject-specific vocabulary was needed.

The density of technical vocabulary was also commented as prohibiting comprehension of the notes the students were taking during the lessons. One student in Christina's class explained that often students were very busy copying down the information on the PPT slides and did not have time to comprehend what these words mean or paying attention to the teacher's explanation. Many students only became clear about the lesson content through reading notes and textbook pages after class.

To overcome the challenges associated with high lexical density, some students proposed that more pauses in teachers' talk would be helpful to allow more time for students to look up new technical vocabulary as they hear them. One student mentioned in the post-lesson interview after Christina's first lesson that there were many new technical vocabulary to them, such as '*magma*', '*tectonic*' in '*plate tectonic theory*'. They were key vocabulary items in that lesson

and were repeated several times. However, the students commented that they still did not understand the meaning of these words until after the lesson. One student explained that it would be more helpful if the teacher could pause her teaching from time to time and give students some intervals to look up new words in their dictionary. This reflects the struggles some students had during teachers' monologues, which were frequently used in the lessons, shown in Chapter 4 Results for Classroom Interaction.

The findings above also echo with students' answers to Questions 6(a) and 6(b) in Section 3 of the student beliefs questionnaire, presented in Section 6.2.2 of this chapter. There students also pointed out the high quantity of technical vocabulary was the biggest challenge for them to learn science through English. The findings here also align with students' clear need for teachers' explanation of difficult words in textbooks or text-based notes, shown in Item 8 in Section 5 of the questionnaire.

The students' answers here also provided further clarification regarding the students' limited recognition of the language of science as a problem in Item 3 of Section 5 of student questionnaire. Considering the clear identification of technical vocabulary as a challenge in the interviews, the speculation of the students not having fully understood '*the language of science*' in Item 3 is reinforced.

6.5.1.2. Non-technical vocabulary

Although overall the students did not think general English was a problem for their learning of science through English, shown by the result of Item 4 in Section 5 of the student beliefs questionnaire, the post-lesson interviews revealed several cases where non-technical vocabulary actually caused trouble in students' comprehension of key science concepts.

One example was shown in the interview after Christina's first lesson on *plate tectonics*, where *magnetic stripping* was among the key concepts. In the post-lesson interview, both students specified that they did not understand how magnetic stripping took place and why different brands of rock in the sea floor record different polarities. It turns out one student did not know the meaning of one of the key words in the teacher's explanation - '*ridge*', and the other student misunderstood the meaning of it as 'two sides', which is relevant but not exactly correct. This word is a non-technical word, based on the distinction made in Section 2.3.4.4.2.2 in Chapter 2. This example reveals the situation where non-technical vocabulary, which is most likely familiar to L1 students, could stand in the way of EMI students' comprehension of a science idea. As observed in this lesson, the teacher also did not explicitly explain the meaning of this word.

Incidents like this in the interviews also help to explain the students' answers in the open-ended questions in the questionnaire where they specified a lack of knowledge about vocabulary and a low proficiency in English in general caused problems in their communication and interaction with the teachers. Thus, the findings from the interviews and the questionnaire overall suggest that although the students might not have clearly identified general English a problem for their science learning, the difficulties caused by general English, e.g., the non-technical vocabulary, in their comprehension of science ideas did exist.

6.5.1.3 Interaction with teachers only through L2

When being asked about their interaction with the teacher in the lessons observed, several students mentioned that they preferred listening in class because asking questions would slow down the teaching. This also coincided with the finding of the open-ended Question 22 in Section 5 of the questionnaire, where many students considered asking questions taking time away from the teaching of science content and lowering the teaching efficiency.

The difficulty of accurately phrasing questions in English was also commonly mentioned as a reason for not asking questions. It was frequently mentioned that teachers may misunderstand

them and provide an explanation on something different. Some students also expressed the worry that they may not fully understand the foreign teachers' explanations and they would need to think about how to ask further questions. It was mentioned that many students would ask teachers questions after class individually. This difficulty of communication through L2 only with the monolingual teachers was also commented as a main reason for many students' reliance on discussing among peers in Mandarin, reading textbooks and notes and looking up information online in their L1 to figure out questions themselves. As one student clearly put it,

> '*I hope the teacher could use only half of the lessons to teach and then give us the other half to discuss with each other. We want more discussion. So, we could ask each other. We don't usually ask the teacher, because then he will talk even more, and this may be even more difficult for us. So, we prefer asking each other in Chinese.'*

Here the students' strong need for more group discussion time was clearly shown, which also reflects the difficulty they faced in communicating clearly with their monolingual teacher.

These answers from the interviews provided certain clarification to the conflict mentioned earlier, where only a small proportion of the students recognized a lack of English proficiency as a reason for their lack of participation in the multiple-choice Question 3 in Section 3 of the questionnaire but the lack of linguistic resources was identified as a main reason for not participating in classroom interaction in the open-ended Question 22 of Section 5. The clear theme of the language difficulty found in the interviews reinforced the students' answers in the open-ended Question 22 and provided more evidence that perhaps the answers given to the multiple-choice question did not accurately reflect the reasons of not participating in classroom interaction.

6.5.2 Effective strategies for science learning

The students also mentioned a variety of strategies or methods their teacher used, or methods of learning science they used themselves. Some of these strategies indicate the alignment of students' beliefs with the constructivist framework and some reflected a more transmissionary

view of learning science. The main strategies that students considered important include doing ample practice questions, teachers' use of visual aids, and asking teachers' questions.

6.5.2.1 Doing practice questions

Several students from different classes mentioned that they developed understandings of science ideas mainly through doing practice questions and listening to the teacher's explanations of how to answer these questions. One clear example was given from Louis's first lesson on ionization. Both students commented doing practice questions on the worksheet (see Appendix 22 for an example page) used in the lesson was very effective in helping them understand about the ionization of arsenic acid. One student specified that '*learning science is about doing practice questions*' and the most effective way of learning science is '*teacher introducing concepts first, then us doing practice questions, followed by teacher's explanation of how to answer these questions, and in the end doing practice questions that combine the knowledge throughout the whole chapter*'. Here a clear emphasis on listening to teachers' introduction of new knowledge and doing practice questions to consolidate the knowledge was shown. A concern for passing exams was also often mentioned and doing past exam papers was perceived as an important strategy for science learning. The interactive process of learning science and discussion of ideas were not given much attention. However, the nature of the practice questions was not explored in this study, which could make a difference in the learning process and thus the students' beliefs demonstrated.

This view of highlighting doing ample practice questions also aligns with one of the common themes in the open-ended questions 17 and 18 in Section 4 of the student beliefs questionnaire.

6.5.2.2 Teachers' use of visual aids (drawing, diagrams, pictures)

Another effective way of learning science mentioned by several students was visual aids, including teachers' drawing, diagrams and so on. Many students pointed out how teachers'

drawing helped them understand science concepts. For example, the students in Chris's class commented that the teacher's drawing of total internal reflection on the board, shown in Figure 23 below, helped them understand this concept.

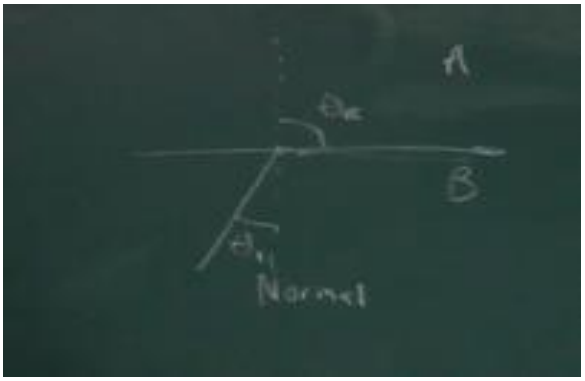

Figure 23 example of visual aids in Christ's lessons

Similarly, students in Kate's class also provided clear explanation of how diagrams of the temperature and precipitation, as shown in Figure 24 below, helped them understand the characteristics of different biomes, such as the one below. One student commented that '*these diagrams are much more straightforward than the lengthy texts in a second language where lots of new words may appear'*.

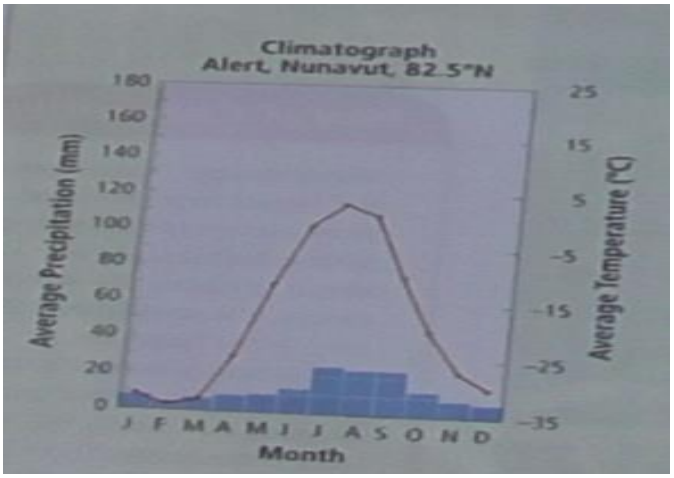

Figure 24 example of visual aids in Kate's lessons

Another case was from Mat's first lesson on Biotechnology. The students mentioned that the teacher first introduced the process of genetic modification by showing a picture on PPT, and then the teacher drew the picture on the board step by step and explained. This was very

effective in helping them understand the procedure thoroughly and the terms written on the picture and on the board also made sure they knew which words were being used.

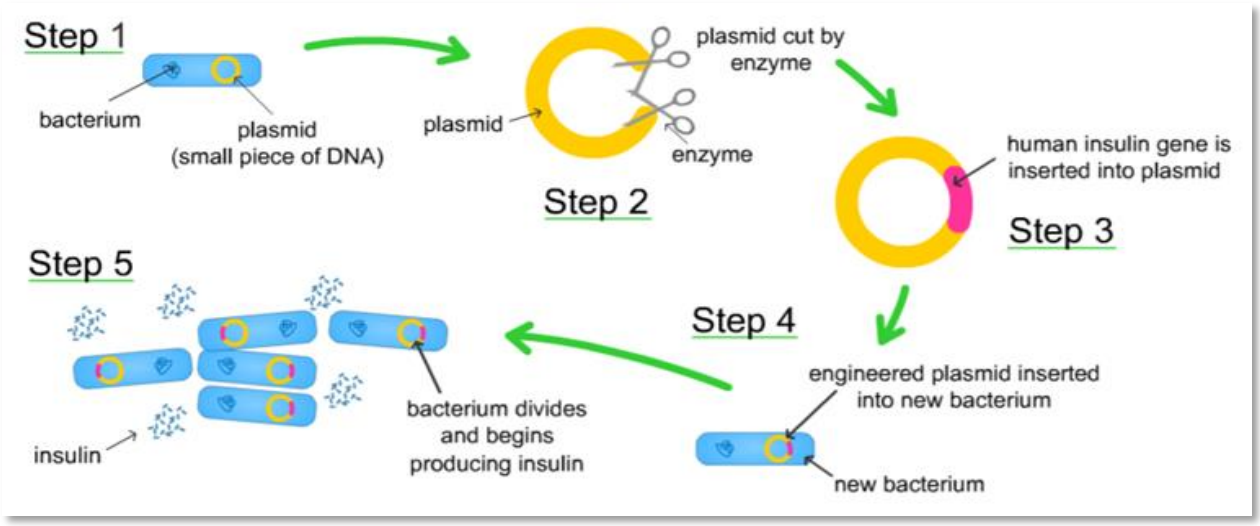

Figure 25 example of visual aids in Mat's lessons

6.5.2.3 Asking teachers questions

While doing ample practice questions emerged as the most common strategy for learning science in the post-lesson interviews, a smaller number of students also specified the value of teachers inviting students to ask questions. Although a few students mentioned they would prefer not to ask questions in class, the cases where asking the teacher questions was specifically commented on as helpful were considered worth reporting and exploring. This is because the primary focus of this study is on classroom interaction.

There were several examples mentioned in the interviews. For instance, in Hannah's first lesson in Biology about the life cycle of gymnosperm, a student explained that it was very useful that the teacher asked the students if they had questions and this process of asking questions also allowed the teacher to understand students' difficulties. She mentioned she did ask a question, which was about the four haploid cells in the seed that was shown in one PPT

slide. Excerpt 30 below is the corresponding episode from the lesson observation. The student explained that the teacher's explanation helped she understand the ideas more fully.

Excerpt 30

Turn	Timespan	Content	Speaker
38	6:09.0 - 6:17.0	Any questions? [pause 2 seconds] Anything that you don't quite understand, and you need me to explain it?	T
39	6:17.0 - 6:34.0	[wait time]	T
40	6:34.0 - 6:37.0	What is the four haploid cells for?	S3
41	6:37.0 - 7:31.0	Four haploid cells. Now the female is more complex than the male. Surprise, surprise. Okay? Remember the female is going to develop into the seed. And this seed has food. [T pointing to the slide] The four haploid cells talk about how from the part of meiosis, some of those cells would become the food, and one of those cells could become the, zygote in embryo. Okay? So that's what it's talking about, about the four haploid cells. We're gonna talk more about that when we do flower reproduction. [pause 2 seconds] We'll talk about how other seeds develop into the food.	T

Although in the lesson observations student questions were rather rare, some students did show acknowledgement of the importance of asking the teacher questions and letting the teachers know their difficulties.

6.5.3 Effective strategies for language learning

Strategies that students perceived as helpful for language learning were also mentioned in the interviews. The main strategies mentioned include looking up words in L1 and teachers' explicit explanation of vocabulary.

6.5.3.1 Reliance on Chinese

The most mentioned strategy was looking for Chinese translations. Often the students looked up new words during lessons as they encountered them, asked their peers, or marked down the Chinese translations before lessons. Hopes were often expressed for having the Chinese

equivalent of certain technical vocabulary provided in time during lessons. Some mentioned that they did not know the meaning of certain key terms until they looked them up and realized they actually already knew this concept from their CMI schooling before. This reflects certain level of background science knowledge the students already possessed, and the help access to previous knowledge could provide to the students. One student in Stella's first class on the structure of plants explained that

> '*Actually, we learnt some of the biology concepts in this lesson already in junior secondary school and in this lesson, we were learning them again through English. So, when the teacher described them, we were trying to remember what we learnt before.*'

She continued to provide one example on how she tried to match technical vocabulary in English with the Chinese equivalents-

> *'When we saw the definition on the PPT that xylem transports and stores water and phloem transports sugar and proteins, we realized the Chinese terms for xylem and phloem because in junior secondary school we learnt that 导管 (xylem) and 筛管 (phloem)' respectively transports water, and proteins and nutrients.'*

She commented that through realizing what these terms mean in L1, she could access all the information she learnt before about these concepts. A similar case was also reported in Hannah's first lesson. A student commented that she was unclear about the exact meaning of '*cotyledon*' in the beginning, but when she knew the Chinese equivalent was '子叶' (cotyledon), she realized she had learnt this concept in junior secondary school already.

Many students also mentioned L1 translations were helpful in making connections between past experiences and new science ideas. For instance, in the post-lesson interview after George's first lesson on different types of sugar, the students mentioned that before they looked up the word '*lactose*', a key word used repeatedly in the lesson, they did not realize this term was '乳糖' (lactose) in Chinese, which they actually frequently saw in their everyday life, such as on the labels of milk products.

Because of the desire for L1 translations, many students mentioned that they would spend substantial amount of time looking up the Chinese meaning of new words before and after lessons. As one student from Hannah's class commented:

> '*If you don't preview the textbook pages before the lessons and look up the new words, you have a difficult time understanding the class. Because this chapter is difficult, the teacher also asked us to preview the relevant textbook pages before class. We also looked up the new words ourselves before the lesson, such as magma, meaning 岩浆 (magma).*'

In the case where the Chinese equivalent terms are also new to students, several students commented that they still preferred knowing them because this way they could use this term in Chinese to search more information on the internet and read more extensively about this concept in Chinese. Chinese translations were indeed often observed in students' notes and textbooks and the students were very often observed to look up words in their English-Chinese electronic dictionaries during classes. The first picture, Figure 26, below comes from a student in Hannah's lesson on the life cycle of angiosperm, and the second picture, Figure 27, comes from a student in Kate's lesson on biomes.

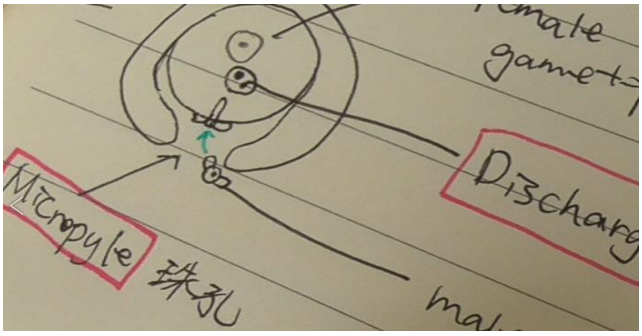

Figure 26 a student note with L1 translations

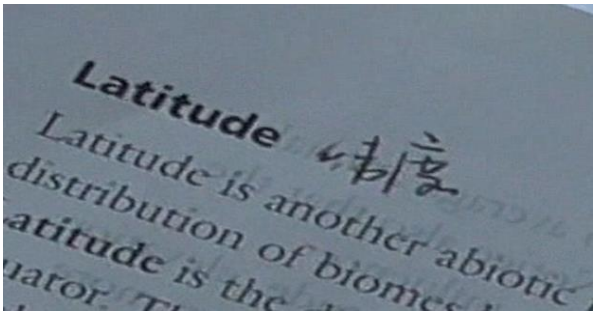

Figure 27 a textbook page with L1 translations

This theme of students' reliance on Chinese also echoes with the findings of the open-ended Question 22 in Section 5 of the student beliefs questionnaire on the challenges for participating in interaction. There many students also reported they very often needed to search for L1 translation and relied on themselves on figuring out the science knowledge learnt. This finding also highlights the difference between a bilingual EMI science teacher and a monolingual teacher who cannot give these L1 translations and therefore the students spent a substantial amount of time and effort to search for it themselves.

6.5.3.2 Teachers' use of vocabulary worksheet and explicit teaching of vocabulary

In the post-lesson interviews, the students often commented they found useful their teacher's practice of providing a list of key vocabulary at the beginning of a chapter for them to look up, and teacher's explicit explanation of important or unknown vocabulary during lessons. In the lessons observed, this practice was coded as 'language-focused episodes'.

Several examples of vocabulary sheets provided by teachers can be found in Appendix 23. In Hannah's first lesson, both students mentioned that the vocabulary sheet the teacher provided to them at the beginning of the term was very helpful. As can be seen, this vocabulary sheet is about the meaning of the common prefixes and in suffixes in Biology. Similarly, Christina also provided students a list of key vocabulary at the beginning of the chapter on plate tectonics and students commented this helped them get prepared for better comprehension in lessons. Throughout the whole chapter, the students were required to write down definitions, or use drawings and examples to explain these words. At the end of the chapter, they would submit this worksheet to the teacher. The students commented that the teacher required them no to use the exact same words as the explanations in the glossary at the back of the textbook and required them to use their own words to show their understanding. The same practice was also mentioned by students in Colin's class. One student commented that '*it's useful that we were given the vocabulary sheet before the lesson so that we could look up the words first, and then in the lesson, we know what the teacher talks about*.' Colin was also observed to spend a

substantial amount of the lesson time in his first lesson going through the list of vocabulary and work on the pronunciation and meaning of the key words in the new chapter.

While many students commented that the teacher's explicit explanation of vocabulary was helpful, some also mentioned the explanations or definitions provided by the teachers could be difficult for them to understand. For example, in Chris's first lesson, a sizable proportion of the lesson was dedicated to the teacher's typing up on the screen the meaning or definition of the vocabulary that students had problems with. A screenshot is below:

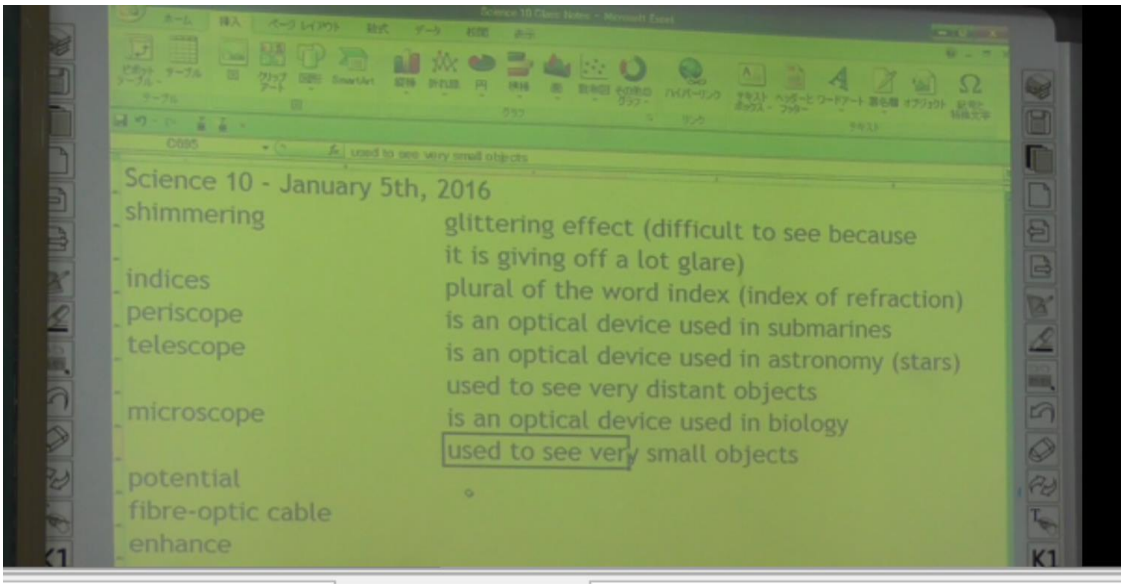

Figure 28 a screenshot of Chris's explicit explanation of new words

Here, the teacher invited the students to let him know the difficult vocabulary they encountered in textbook pages and in lessons, and he then provided explanations and typed them up on the screen for the students to see. In the post-lesson interview, both students explained that because of their limited English proficiency level, they were not competent enough to understand the teacher's explanation in English and would prefer Chinese translations. One student commented that '*often I feel the next time I see these words, I still do not know what they mean*'. Here, the theme of needing the Chinese translation emerged again. One example given by a student is that she looked up the Chinese meaning of '*periscope*' in the lesson using her electronic dictionary, which is 潜望镜. She commented that this was more effective than the teacher's explanation '*periscope is an optical device used in submarines*', as shown in the screenshot above.

6.5.3.3 Other strategies

Apart from the above-mentioned strategies for language learning in EMI science classes perceived effective by the students, other useful strategies were also mentioned, which were not brought up as frequently, but nonetheless revealing students' opinions on these strategies.

One of these strategies is teachers' use of language-laden quizzes, commented as helpful for promoting language learning by the students from Colin's class. An example of such quizzes is given in Appendix 24. A student mentioned that:

> *'The teacher wanted to see how much of what he said was understood by the students, or apart from the Chinese translations which students rely on, how much English the students understand. I think it is good because it can test how much we understand the English language, and I am not good at English, so it's helpful to me.'*

This appreciation also echoes with some teachers' comments in their interviews on how they designed the assessments they used to incorporate more comprehension and production of the language. Another student from Colin's class also explained that it was not necessary to remember all the formula in the quiz, but the teacher would use different ways of naming the formula they learnt and assess if they understand the language describing the science concepts. The students' opinion on language-laden quizzes align with Colin's comments in an interview where he also perceived the use of these quizzes a strategy for effective teaching of English in the EMI context.

Other strategies include guessing the meaning of words through diagrams, and teachers' explicit explanation on how certain words could have a different meaning in science, such as '*solution*'.

6.5.4 The influence of Chinese medium instruction (CMI) science classes on classroom interaction

As explained earlier, in many of the foreign high school programs the students also took the core subjects in the Chinese high school curriculum that often ran in the late afternoons, scheduled after the foreign curriculum classes. The students often took the public exams for Chinese high school diploma during the first and second year of their high school to ensure they can still obtain the high school diploma in China despite their plan of going abroad for university education. Because of this exposure of CMI science classes, the students were asked in the post-lesson interviews whether they thought CMI classes influenced the way they interacted with the foreign teachers in their EMI science classes observed. The same question was also asked in the teachers' interviews.

Similar to the teachers' comments, most of the students mentioned that the content learnt in the EMI classes observed was mostly new to them, although sometimes they had learnt some basics about the target topics in their CMI junior secondary school. The students explained that in most cases there was still substantial expansion or more depth of the topics introduced in the EMI science classes. The students commented that the learning and participation in teacher-student interaction was not influenced much by the CMI science classes. Some students also stated that having some existing knowledge about the science topics introduced in EMI classes also helped them to be more confident and at ease with interacting with the teachers.

6.5.5 Summary of the interview findings

The high quantity of technical vocabulary, again, emerged as the main challenge for students. A need for the teachers to be more aware of this difficulty was clear from the student interviews. As specified by many students, more pauses in the teaching to allow students time to look up new words and process the input would be perceived more helpful. Although the students themselves did not explicitly acknowledge the problem of non-technical vocabulary in the interviews, the discovery of the incidents where non-technical vocabulary caused problems for students' comprehension of science ideas also provides important insights that

not only technical vocabulary was a challenge, but also likely the non-technical vocabulary contained in science explanations.

Insights about students' difficulties for participating in classroom interaction were also revealed through interviews. Firstly, some students saw asking questions as slowing down the teaching and taking away time for the teacher to introduce more knowledge. This also provides confirmation of the findings of Question 17b and 18b in Section 4 of the student questionnaire, where the same view was also expressed by many students. Secondly, the lack of linguistic resources to phrase questions accurately to ask teachers was another main difficulty. This also aligns with the difficulties mentioned in Question 22 of Section 5 of the student questionnaire on difficulties for participating in classroom interaction. As a consequence, the students often mentioned that they preferred discussing with peers in L1 and a hope was expressed for more group discussion time in class.

Among the variety of strategies perceived by the students as effective for science learning, the most frequently mentioned ones were mainly for consolidating new knowledge learnt and addressing the language difficulties. The main strategy of previewing and revisions to look up new vocabulary shows the students' main concern of the language issue, which is mostly vocabulary here. The highlight of doing ample practice questions and exam papers, which were also main themes from the open-ended questions in the student questionnaire, again suggests a major concern that students had for performance in exams. The strategies related to learning through interaction were mentioned rather infrequently in the interviews.

The appreciation of the teachers' strategy of using visual aids also reflects, similarly, the students' concern of the language difficulty in their learning of science through an L2 and the issue of comprehension of input. Although visual aids are also considered an effective strategy for science learning in the L1 contexts, the findings in this study reveal that the straightforwardness of these visual aids was considered especially helpful when in the EMI contexts students are exposed intensively to an L2 in a subject domain. In addition, the written form of the terminologies as a type of visual aids also ensures the students knew the words used in teachers' utterances. The students' appreciation of visual aids also corresponds with the teachers' comments in the interviews where visual aids were mentioned as a strategy to

make abstract concepts concrete.

Regarding students' own strategies for language learning, the most commonly mentioned ones were looking up Chinese meaning of new technical vocabulary and teachers' explicit teaching of vocabulary. The main reasons for the need of L1 translations, as explained by the students, include for gaining access of science knowledge previously learnt through L1, making connections with the everyday life experience, which is in L1, and the difficulty of understanding the teachers' L2-only explanations. Similarly, the role of interaction with teachers was also rarely mentioned here for effective learning of English. This rare mentioning of interaction suggests that the students' awareness of the role of interaction for L2 learning may not be deeply ingrained, especially when there was no probing about it in the questions.

6.6 Summary of the chapter

This chapter presented the findings from the student beliefs questionnaire and the post-lesson interviews with students.

The students' motivation of attending a foreign high school program features a clear aim of obtaining tertiary education overseas and a hope for improving English. This provides important background information in understanding of the students' beliefs and the classroom interaction they engaged in. While the hope for fostering critical thinking was another reason often mentioned, certain findings on the students' beliefs about effective science learning show contradictions to this hope.

Variations were also observed on students' beliefs about different issues. The students demonstrated a more constructivist view point on some issues but a more transmissionary view on others. The students believed in the general value of interaction for both science learning and language learning, but their view became less clear when a more teacher-dominated option

was presented. The reasons for the variations will be explored in Chapter 7 Discussion and Conclusion.

Regarding language learning, different levels of attention were shown to different aspects of language. While the language of science and vocabulary were clearly recognized as important areas to focus on in EMI science classes, explicit teaching of grammatical features common to science texts received considerably less attention. These differing levels of attention indicate that the students perhaps did not consider the grammatical features that are commonly used in science texts, e.g., passive voice, part of the language of science, important to learn. The high quantity of technical vocabulary emerged as a main language concern for the students. The lack of focus on grammar and strong attention to vocabulary suggests that the students might mainly see technical vocabulary as the main component of the language of science and did not realize the important role grammar plays in the language of science.

Another area of language that received less attention was non-technical English. The students overall did not consider general English a problem in the beliefs questionnaire. However, they did frequently mention their lack of general English proficiency inhibited them from participating in classroom interaction with the teacher. Cases were also observed in the post-lesson student interviews where non-technical vocabulary were found to have caused students problem in comprehending science content. The lack of consistent recognition of the role general English plays will also be elaborated in Chapter 7 Discussion and Conclusion.

Overall, the students expressed a hope to improve their English in EMI science classes but showed limited recognition that English learning should be a focus in their EMI science classes. A more communicative and implicit approach emerged as their preferred way of learning English in EMI science classes. A need for L1 was also clearly expressed mainly to tackle the difficulty posed by the high quantity of unknown technical vocabulary, access previously learnt science knowledge, make connection with everyday life experience and understand new vocabulary when the L2-only explanations provided by the teachers were not clear.

Chapter 7 Discussion and Conclusion

7.1 Introduction

This study explored a newly emerging EMI scenario in China, i.e., foreign high school programs where a curriculum of an Anglophone country is taught by a high number of foreign monolingual teachers. The teachers were defined as monolingual teachers in the sense that they do not speak the L1 of the students. As one of the first studies to gather empirical evidence on the foreign high school programs in China, this study aims to start to understand the teaching and learning in this context through the lenses of two constructs – classroom interaction and beliefs.

This chapter first outlines the teachers' professional background and the students' academic background, providing contextual information for the discussion of classroom interaction and beliefs. Then, interpretations are made of the findings of classroom interaction to understand the science and English learning in the lessons observed. Connections are made across the 12 parameters of classroom interaction to provide a comprehensive picture. Then, findings of teacher beliefs and student beliefs are brought together to identify the matches and mismatches between the two. Based on the discussion of all the findings, a summary is provided of the difficulties of implementing a constructivist teaching approach and creating favourable conditions for L2 learning found in this study. The limitations of this study are also summarized. In the end, the contribution of this thesis is presented and implications for pedagogy and research are provided.

7.2 The background of the teachers and the students

7.2.1 Teachers' professional background

This study indicates, based on a small sample of 15 teachers, that many of the foreign monolingual teachers in the foreign high school programs in China are likely to be young with limited past teaching experiences, particularly in EMI science contexts. They are likely to have recently started teaching science subjects in China through English, and possibly had ESL/EFL training and teaching experiences in the past. Another distinct group in the population could be

teachers that are much more experienced and at their 50s, who have taught for many years in their home country and recently relocated to China.

The monolingual teachers' experience with ESL/EFL presents a clear contrast with the existing literature on EMI bilingual teachers. In many studies featuring bilingual EMI/CLIL teachers, the teachers were found to not have any prior training on language teaching (e.g., Barwell, 2005; Fortune et al., 2008; Lo, 2017). A similar scenario to this study where foreign EMI teachers from majority English speaking countries were hired to teach local students was Toth's (2018) thesis, situated in a primary school in Sweden. However, unlike this study, Toth found that the foreign non-Swedish-speaking teachers did not have specific ESL/EFL training in their professional background. Thus, the experience with ESL/EFL may be a special feature with the monolingual EMI teachers in the foreign high schools in China. The ESL/EFL training and teaching experience that many of the teachers had in this study suggests that the foreign monolingual teachers may possess a certain level of ESL/EFL pedagogical awareness. As shown in Chapter 5, the teachers in this study were found to have a certain level of language awareness and understanding of language teaching pedagogy. Their past experience with ESL/EFL could have contributed to it.

Another distinctive feature of the monolingual teachers' background, as compared to the bilingual EMI teachers in the past literature, is the monolingual teachers' limited EMI teaching experience. Many bilingual EMI teachers in the literature were typically described to have taught in EMI contexts for a number of years (e.g., Escobar Urmeneta, 2013; Lo, 2017). This is unsurprising as bilingual EMI teachers are usually local teachers while the monolingual teachers are likely from majority English speaking countries. Thus, this study shows that the monolingual EMI teachers in the context of this study may have more past ESL/EFL training and teaching experience than the typical bilingual EMI teachers described in the past literature, but they may have less EMI subject teaching experience.

The experience with having learnt an L2 or L3 reported by several monolingual teachers indicates a favorable feature in the monolingual teachers' background for facilitating EMI students' language learning. This similar experience of learning a new language means the teachers may have some level of understanding of their EFL students' language needs (Ellis, 2006; Woods, 1996), as explained in Section 2.5.1 in Chapter 2. This knowledge may also have contributed to their teacher language awareness (Andrew, 2001; 2007).

The finding of four teachers having had no academic qualifications or training in science raises the question of on what grounds the monolingual teachers were hired. In these cases, it seemed the proficiency in English was the priority as compared to the science subject qualifications, although they were hired as science subject teachers.

Although the teacher sample of 15 is small, considering the sampling framework and sampling procedure taken, as introduced in Section 2.2 in Chapter 3 Methodology, a reasonable level of external validity was achieved. It is believed that the findings can to a reasonable degree reflect the monolingual teachers' professional profile in the foreign high school programs in China.

7.2.2 Students' characteristics

The students were new to the EMI experience in the foreign high school program. Their clear aim of obtaining tertiary education overseas and improving their English underscores their motivation for attending the foreign programs. This should be born in mind in interpreting their beliefs about science and English learning in EMI science classes. Although without standardized test scores, teachers' comments show that the classes of students in this study represent a variety of English proficiency and academic attainment levels, again indicating a reasonable level of external validity to represent the target student population.

Compared with the past EMI literature, what is new in this study is the relatively stronger science background knowledge the students were commented to possess and their weak English proficiency in comparison. This finding of the concern of some students' lack of English proficiency echoes with the common finding in the literature where EMI students are often described as struggling with English (Choi, 2013; Evans & Morrison, 2011; Kang & Park, 2005). However, the finding of students' strong content knowledge background, perceived by their teachers, is not common in the existing EMI literature and indicates a possible distinctive feature of the students in the context of this study.

7.3 Classroom interaction between monolingual science teachers and Chinese students in foreign high school programs in China

Findings of the 12 parameters of the classroom interaction are connected in this section to provide implications of the degree to which the classroom interaction between the monolingual EMI teachers and the Chinese students benefits science and English learning. References with previous literature on classroom interaction with bilingual EMI teachers are also made.

7.3.1 The quantity and quality of student output

The classroom interaction behaviour in this study features a clear and consistent pattern of teacher dominance and limited student output regarding quantity and quality. This finding resembles the typical classroom interaction pattern described in previous studies with bilingual EMI/CLIL/immersion teachers (e.g., Dalton-Puffer, 2007; Harley et al., 1990; Lin, 2006; Lo & Macaro, 2012; Mantello, 1996; Yip et al., 2007), elaborated in Section 2.3.4.1 in Chapter 2.

7.3.1.1 Quantity of student output

The quantity of student output is low, demosntrated by the time proportion of 11% and an average turn length of 3.5 seconds. This short average turn length is very much similar to the average student turn length of 3.16 seconds found in Pun's (2017) work, where classroom interaction behavior in EMI science classes in secondary schools in Hong Kong was also quantified. As highlighted in Tsui's (1995) book, the success of students' active involvement in classroom interaction is largely dependent on the turn-taking behaviors between the teacher and students. In this study, the small number of student turns and the short student turn length suggest a rather limited degree of student involvement in classroom interaction, which is in line with the findings with bilingual EMI teachers.

The finding of the number of teacher turns being approxmiately twice the student turns indicates a triadic pattern of dialogue following the structure of IRF, which indicates few cases of negotiation of meaning for language learning. As explained in Section 2.3.4.1 in Chapter 2, IRF was developed based on data from L1 subject classrooms and most classroom discourse follows

the IRF structure where typically two acts come from the teacher, I and F, with one act from the student, R (Atkins, 2001; Sunderland, 2001). However, in EMI classes where ample opportunities for negotiation of meaning could be available for language development, the structure of triadic dialogues in this study reflects a possible lack of negotiation of meaning. In an EMI class where negotiation of meaning often takes place, the conversation structure would involve more student initiations to ask for clarifications, or more extended IRFRF sequences with more teacher requests to ask for students' modifications of their previous output. These behaviours would reduce the rigidity of a three-act IRF cycle. The same finding of a triadic conversation structure was also found in Dalton-Puffer's (2007) work with bilingual CLIL teachers in secondary schools in Austria. Similarly, Dalton-Puffer also raised the question of how much language learning was integrated in these CLIL classes, considering the triadic turn taking pattern.

The findings discussed above show that even when the EMI teachers possess high English proficiency, the classroom interaction pattern is still very much teacher-dominated and the quantity of student output is still low. This study, thus, further proved that using an L2 as the medium of instruction does not necessarily guarantee the integration of language learning. The teachers' high English proficiency did not lead to a high level of classroom interaction, which would favour science and English learning (Alexander, 2004; Long, 1996).

7.3.1.2 Quality of student output

The analysis of the noun-verb ratio of student talk shows strong noun-oriented nature of student output and scant production of verbs. This finding, again, indicates limited opportunities for language learning and science learning. First, the high noun-verb ratio of 4.9:1, together with qualitative analysis of student talk, reflects a limited level of linguistic complexity in student output (Macaro, Graham, et al., 2016). Student talk was found to be often made up with single nouns or noun phrases with no verbs used. However, without experimenting with using verbs and complete sentence structures, students have reduced opportunities to notice the gap between their interlanguage and the target language forms, which are key to language development (Swain, 1985; 1995). Second, the low use of verb indicates a possible lack of sophistication of the science content described in student talk. As science ideas and concepts often involve processes, motions and explanations, which are typically described by verbs, the low use of verbs

in student output suggests reduced likelihood where students fully elaborate their science views. This finding indicates an unfavorable condition for effective science learning, based on the social constructivist view (Hohenstein & Manning, 2010; Jenkins, 2000) and Dialogic Teaching (Mercer & Littleton, 2007) , where students' extensive and thoughtful explanations of their ideas are highlighted as key for science learning, elaborated in Section 2.3.2 of Chapter 2. This study shows that when EMI teachers possess high English proficiency themselves and are unlikely to reduce interaction due to their own language deficiency, student talk could still be not only limited in quantity but also in terms of linguistic complexity.

7.3.1.3 Student questions

The findings about student questions provides another perspective to understand the quality of classroom interaction in this study. The minimal presence of student questions, i.e., 2.4 student questions per lesson on average, shows a lack of students' attempts to make enquiries, which is a key indicator of active participation in the constructivist view of learning (Beck, Czerniak, & Lumpe, 2000; Gil-Pérez, Guisasola, Moreno, Cachapuz et.al, 2002). The low number of student questions also means reduced possibility for teachers to understand the students' own conceptions or misconceptions, which allows teachers to steer their subsequent teaching.

The types of student questions indicate mostly lower-order thinking processes and thus limited opportunities for science learning. Lower-thinking questions made up the majority of the student questions (i.e., 28.2% *memory questions* and 32.4% *convergent thinking questions*), which reflects thinking processes confined to seeking factual and straightforward answers obtained through a restricted and controlled knowledge framework (Gallagher & Aschner, 1963). The students barely made more open-ended enquiries which demands synthesizing existing knowledge to create new understanding, as would be demonstrated in *divergent thinking questions* and *evaluative thinking questions* (Gallagher & Aschner, 1963). However, these higher-order thinking processes are especially important in advancing learning in a constructivist classroom (Wellington & Ireson, 2008). Thus, while few studies have investigated student questions in EMI classes, as explained in Section 2.3.4.3 of Chapter 2, this study found that students seldom asked questions in the EMI context of this study and higher-order thinking questions were very rare.

Another new finding about student questions in this study is the context where the higher-order thinking student questions took place. The only *divergent thinking question* and *evaluative thinking question* that were asked in this study were both in Nicolas's first Biology lesson, consisting of a class debate activity. This coincidence suggests that the use of a student-centred debate activity might have been a reason why the only two higher-order thinking questions in this study occurred in this lesson. This speculation is supported by Van Zee et al.'s (2001) work conducted in an urban elementary school in the US, which explored student questions in classrooms with a variety of instructional activities, including lecture, recitation, teacher-guided discussion, student-generated inquiry discussion and peer collaboration. Van Zee et al. found that students asked more higher order thinking questions in student-generated inquiry discussion and peer collaboration. They argued that student-led discussions create more space for thoughtful questions from students. Thus, this study suggests that in EMI contexts, although with the additional language challenge, the context of student-generated discussion may be a favourable condition to promote more higher-order thinking questions from students.

The language difficulties also were observed in this study for students to clearly put across their questions to the teacher, as shown in Section 4.1.12.4 in Chapter 4. The students often needed to further clarify their questions. This could be partly due to the precise nature of the language of science and the complicated science content described (Halliday & Martin, 1993; Ogborn, Kress, Martins, & McGillicuddy, 1996; Wellington & Osborne, 2001). However, this study found a frequent practice where the teachers cut off the students while they were still trying to complete their questions, as shown Section 4.1.12.4. Although a pedagogical decision in classrooms could be motivated by many factors, this practice does not allow the students the time and opportunities to experiment the language structures in their interlanguage needed for phrasing questions (Swain, 1995), thus contributing to an unfavourable environment for students' L2 development.

Language-related questions from the students were also rare. Only 11.3% of them, i.e., only eight, were language-related. This shows a lack of student effort to signal communication breakdown and ask for clarification of language items. Similar findings were also found in previous literature with bilingual EMI teachers' classes. Badertscher & Bieri's (2009) work reported only 15% of negotiation of meaning incidents were student-initiated in the CLIL classes observed. However, contrasting finding was also found in Mariotti's (2006) work, where student clarification requests

in fact made up the majority of the incidents of negotiation of meaning in the CLIL classes she observed. Thus, with the added evidence from this study, it seems some EMI/CLIL contexts have more student-initiated negotiation of meaning while others have little.

7.3.2 Teachers' effort to promote student participation

While student output was found to be rather limited, an examination of the teachers' techniques of using classroom interaction suggests several possible reasons that may have contributed to the overall low level of interaction.

7.3.2.1 Teacher monologues and the quantity of student output

The teachers were found to frequently use monologues, which indicates a tendency of direct lecturing. As illustrated in Section 4.1.6 of Chapter 4, the teacher monologues often entailed delivery of new knowledge without checking students' comprehension or inviting students to speculate. Although at times authoritarian talk is necessary and there is a need for the teacher to explain concepts without inviting student output (Mortimer & Scott, 2003; Ogborn et al., 1996), the significant proportion of it in this study still reveals the teachers' tendency of transmitting knowledge and giving information uni-directionally. This leaves limited space for constructing knowledge with the students and scaffolding, which is key to the constructivist view of teaching science (Mansour, 2009; Prawat, 1992). From the language learning perspective, the heavy use of teacher monologues could also lead to reduced opportunities for negotiation of meaning where students could request teachers' modifications of their input and could also be requested by their teacher to modify their own output (Gass & Mackey, 2006).

The pattern of teacher monologues shows a high frequency of occurrence (i.e., 13.1 times per lesson on average) but a short average length per occurrence (i.e., 49.6 seconds). The high frequency also mirrors the high number of teacher questions, as a teacher question would mark the end of a teacher monologue. However, the high frequency of teacher monologues reflects the difficulty of maintaining an open conversation with the students. More discussion connecting teacher questions and student output is below.

7.3.2.2 Frequency of teacher questions and the quantity of student participation

The teachers were found to ask questions frequently in this study, which presents a clear difference with the bilingual EMI teachers in previous studies (e.g., Sopia, et al., 2010; Tan, 2011; Yip et al., 2007; Lo & Macaro, 2012), introduced in Sections 2.3.4.1 and 2.3.4.2 of Chapter 2. This study provides initial evidence that when EMI teachers are proficient in English, they tend to open up conversations with students and allocate the floor for students to talk. The monolingual teachers' effort in this study to use questions frequently is considered beneficial for creating opportunities for science and language learning. Teachers' use of questions have been argued to largely determine how turns are allocated and the content of student talk in classes (Chin, 2007; Erdogan & Campbell, 2008; Gall, 1970; Kawalkar & Vijapurkar, 2013; Yip, 2004).

Despite frequent questioning from the teachers, however, it is clear in this study that this did not lead to substantial student output. The pattern of frequent use of repetitions or reformulations of a previous question also reveals the difficulty of moving conversations forward with the students. One teacher factor that might have contributed to the students' limited output is the teachers' often acceptance of the students' fragmented answers and their lack of effort of requiring the students to produce complete sentences and providing scaffolding to assist them.

The students' limited English proficiency is believed to be another factor that contributed to the difficulty of eliciting student participation, despite the teachers' persistence of asking questions frequently and repeating and reformulating questions. As commented by the students themselves, a lack of English linguistic resources was a major reason why the students found it hard to formulate longer answers with a more complicated linguistic structure, and accurately comprehend teacher questions. The language difficulty faced by the students also aligns with previous EMI/CLIL studies (Cho, 2012; Gu & Dong, 2005; Lei & Hu, 2014; Lo & Macaro, 2012; Probyn, 2006) mentioned in Sections 2.3.4.4.2.2 in Chapter 2. However, what is new in this study is that even when the common obstacle of teachers' lack of English proficiency is eliminated, the students' lack of English proficiency continues to limit classroom interaction.

7.3.2.3 Types of teacher questions and the quality of student output

The types of teacher questions largely determine the content of student talk. This is reflected in the cognitive thinking demanded and the linguistic structure used by students (Chin, 2007; Erdogan & Campbell, 2008; Gall, 1970). Findings of this study show the monolingual EMI teachers' overall frequent use of constructivist questions, with prevalent use of two constructivist questioning approaches and an overall lack of variety. The prevalent use of *pumping* demonstrated the teachers' effort for asking students to explain their views and make guesses. The use of *association of key words and phrases* demonstrates the teachers' awareness of EMI students' difficulties with learning a high quantity of technical vocabulary in an L2. However, the other varieties of constructivist approaches, such as *reflective toss, multipronged questioning* and so on, were rarely utilized. This lack of variety reveals limitations of teachers' questioning skills in this study to promote student productive thinking through different angles, which is argued to be at the core of science learning from a constructivist view (Chin, 2007).

Based on Chin's (2007) explanation of the nature of *pumping*, the heavy use of *pumping* in this study is to a degree understandable. As Chin specified, *pumping* is a rather broad and general approach that is basically used to place the responsibility on students to talk rather than the teacher giving '*a mass of information via direct instruction*' (p.824). The use of it could be implemented in a rather straightforward manner, such as the teacher asking '*what do you think?'* or '*can you tell me about xxx*?'. Another factor that also could explain the lack of variety of constructivist questioning approaches in this study is the students' limited English proficiency level. For example, the successful use of *multi-pronged questioning* requires students to understand all the teacher requests in addressing the target topic from different perspectives, process them and produce answers in English. It would be hard to sustain the extensive dialogues if students' English is limited.

The overall frequent use of constructivist questions and the small percentage of *recall* questions, i.e., 10.2% of all teacher questions, present a clear difference between the monolingual EMI teachers' use of questions in this study and the teacher question types found in previous literature, where *recall* questions were often found to be the majority of teacher questions. As mentioned in Section 2.3.4.2 in Chapter 2, bilingual EMI/CLIL teachers were found to heavily use recall questions and rarely use higher-order thinking questions (e.g., Dalton-Puffer, 2007; Menegale,

2012; Schuitemaker-King, 2012; Sopia et al., 2010; Tan, 2011; Yip et al., 2007). The relatively light use of recall questions and sizable proportion of the constructivist questions in this study, despite lacking variety, shows the monolingual EMI teachers' effort to adopt a constructivist teaching approach and promotes higher-order thinking in the students (Chin, 2007; Gagnon & Collay, 2001). This study provides new evidence suggesting that when possessing a high level of English proficiency, teachers are more confident about asking more cognitive challenging questions in EMI classes.

Despite the teachers' frequent use of constructivist questions, however, the student talk elicited was still limited both in quantity and quality, as discussed in Section 7.3.1 above. This is particularly prominent in the teachers' frequent use of *pumping*, where the students did not actually produce substantial information, which *pumping* supposedly invites (Chin's, 2007). This, again, reveals that even when the EMI teachers' own English proficiency does not prevent the teachers from opening up the conversations with the students and asking cognitive demanding questions, it could still be difficult to have student output. The reasons could be the teachers' lack of follow-up effort to scaffold the students' answers through providing the language items needed, and the students' own limited English proficiency.

Making connections with the high noun-verb ratio in student talk, it is speculated that the teachers' relatively frequent use of *association of key words and phrases* questions could have contributed to the prevalent single-noun answers given by the students. However, the number of *association of key words and phrases* questions accounted for only 13.5% of all the teacher questions. Thus, the use of them alone could only to a limited degree explain the prevailing noun-oriented nature of student talk. In addition, Dalton-Puffer (2007) observed CLIL classes in Europe and found that short student responses featuring single noun phrases persists seemingly independent of the type of questions teachers ask. Therefore, this study adds to the evidence that in EMI contexts teachers' use of constructivist questioning approaches alone does not suffice in eliciting substantial student output, even in the situations where the teacher possesses a high level of English proficiency. Again, other limiting factors are also at play, such as teachers' scaffolding strategies and students' English proficiency.

7.3.2.4 Teacher nomination

Teacher nomination is argued to be part of effective teacher questioning and it plays a role in how turns are allocated to individual students (Black & Wiliam, 1998). In this research, teacher nominations were used infrequently, with only 10.8% of the teacher questions followed by a nomination of a student to answer. Thus, the benefits of it were exploited only to a limited extent, such as exploring individual students' existing knowledge, encouraging more participation from various students. These functions are all valuable from the constructivist view of teaching science where teaching is advised to be based on students' existing knowledge (Erdogan & Campbell, 2008).

From a language learning point of view, teacher nominations also encourage various students, particularly the students who do not volunteer to speak up, to test and trial their interlanguage, and possibly make mistakes where the gaps between their interlanguage and the target forms can be noticed. This is a key mechanism for second language acquisition, highlighted in Swain's (1985; 1995) Output Hypothesis. However, the low use of teacher nominations in this study means that the students who did not volunteer to speak up were rarely nominated to answer questions and thus were seldomly pushed to experiment with formulating ideas about science in English.

What also plays a role in teachers' decision of using nominations is the rule of classroom talk the students are accustomed to. It could be argued that the teachers in this study might have realized that nominating a student to speak up in class might be intimidating, and the culture of talk the Chinese students were socialized into was probably different from what the foreign teachers were used to (Gan, 2009). In fact, the students in this study did report a fear of losing face if they make mistakes when they speak up. This factor of the culture of talk was not explored in depth in this study but the important role it plays is acknowledged, particularly in a scenario where the teachers are from different cultures from the students' own (OECD, 2005).

7.3.2.5 Wait time

Wait time is another component of effective questioning, alongside teacher nominations. The appropriate use of wait time has been widely argued to influence the quality of students' responses (Rowe, 1974; Tobin, 1987). In this study, only 18% of the teacher initiations were followed with wait time which was longer than one second. Although the overall low frequency of the use of wait time suggests possible constraints in promoting student participation, the average range of wait time was from 1.7 to 11.2 seconds, which suggests teachers' awareness in differentiating the use of wait time based on the contexts.

The use of wait time depends on a variety of factors, such as the cognitive demand of the question asked, the situation of the students, the rule of talk in the classroom and possibly more. Thus, the understanding of wait time needs to be in relation to the types of teacher questions. As 45.7% of all teacher questions asked were constructivist questioning approaches which aim to promote students' productive thinking (Chin, 2007), it could be argued that at least 45.7% of the teacher questions posed a certain level of cognitive demand on the students. Thus, it could be argued that there was a high quantity of questions that would require a certain amount of wait time in the lessons of this study. In addition, considering the language difficulty the students faced, more wait time was probably needed for comprehending questions and formulating answers in an L2. Thus, the lack of wait time given by the teachers may be one factor that contributed to the low quantity of student output and the simple linguistic structure of their output.

Similar to the use of teacher nominations, the rule of talk in classrooms that students are familiar with may also play a role in teachers' use of wait time. For example, silence may make students feel uncomfortable and thus they feel compelled to provide a quick answer rather than taking the time to think. Students who are nominated to answer but are given lengthy wait time may also feel embarrassed as it may seem to the whole class that they are struggling. Thus, it is a real challenge finding a balance between creating an optimal condition for students to think carefully and not placing too much pressure on students. As OECD's (2005) report on formative assessment stated, in classrooms where the students are from a different culture background than the teacher's, the teacher needs to consider the cultural expectations and preconceptions about certain teaching techniques and need to put extra effort in helping students feel safe to take risks in answering questions.

7.3.2.6 Extended IRF sequences

Half of the IRF sequences used in this study were single-cycled IRFs, with the other half being extended IRFs. This suggests that the short and disconnected IRF exchanges were still common in this study. However, the extended IRFs did occupy a sizable proportion in comparison with the findings from Lo's (2010) doctorate thesis exploring bilingual EMI teachers in secondary schools in Hong Kong. Although without quantitative results on extended IRFs, Lo found that the EMI teachers were reluctant to engage in extended IRF sequences or ask questions because of the difficulty of eliciting answers from the students and long time it took. The monolingual EMI teachers in this study, however, demonstrated more persistence in asking follow-up questions and using extensive dialogues with the students, which is believed to be a favorable condition for science learning (Littleton & Howe, 2010; Mercer & Howe, 2012; Mercer & Littleton, 2007).

Although a fair quantity of extensive IRFs were used, many of them consisted of repetitions and reformulations of previous questions. This means that many of the cycles in the extended IRFs were not actually about asking new further questions, but repeating the same question. This in a way reduced the believed benefits of extended conversations between the teacher and students, as cited above. The pattern of repeated and reformulated questions shows that in EMI classes teachers often need to modify their questions again and again, which makes it harder to move the conversations forward. Thus, it is of prime importance that EMI teachers pre-modify their input and detect possible causes for difficulties when there were no answers or incorrect use of language in students' answers.

The absence of L1 to elicit answers may also have contributed to the difficulty of receiving student answers in this study. This presents a unique challenge for the monolingual teachers. Then & Ting's (2011) study discovered that when facing the difficulty of eliciting student responses, bilingual EMI teachers switched to L1 and they were more likely to receive students' responses. In this study, however, the monolingual teachers had to frequently repeat or reformulate their questions, but they still often received minimal responses. This suggests the challenges an L2 only environment may bring for successful use of an interactive and constructivist teaching approach. Without much contribution from the students, the core of the constructivist teaching approach is compromised. Together with the finding about students'

difficulties to clearly phrase their questions, as discussed in Section 7.3.1.3 earlier, this study shows that in an L2-only EMI classroom where the teachers have a high level of English proficiency and the students have a low English proficiency level, it was difficult for both the teacher and the students to put across their questions to the other party, have extended conversations, and thus realize a constructivist learning environment.

7.3.3 The use of instructional activities

As the teacher-whole class interaction time on average only occupied 55.7% of the lesson time, what happened outside of the interaction time can also provide significant insights on the learning environment of the EMI science classes in this study. The activity that took up the biggest time proportion was students' self-practice, where students were doing exercises in textbooks or worksheets. Based on the lesson observations, it seems most of the exercises were for reinforcing what was taught. However, the content of these exercises was not systematically examined.

Group discussion and practical activities, which are considered of significant pedagogical value in the constructivist view of teaching science, depending on how they are used (Kang & Wallace, 2005; Tobin, 1986), both took up a relatively small amount of the lesson time. As explained in Section 2.3.2 of Chapter 2, engagement in practical activities is important for students' construction of science knowledge (Jenkins, 2000; Marshall, 1992). From the constructivist view, students should be encouraged to conduct experiments themselves and be given opportunities to provide their own reasoning for the results. However, the minimal use of hands-on practical activities in this research suggests a considerably limited presence of this important component of an optimal science learning environment. Regarding group discussion, the Dialogic Teaching approach highlights discussion among peers highly beneficial as students are given the space to explain their ideas and discuss different views (Mercer & Howe, 2012). Hence, the low time proportion of group discussion in this study also suggests a less favourable condition for science learning.

7.3.4 Explicit focus on English

The importance of language support has become apparent considering the difficulties to elicit student output, the limited length and linguistic complexity of student output, and the challenges for both the teachers and students to comprehend each other's questions. This section discusses the implications of the minimal presence of LFEs (language-focused episodes) in the lessons of this study, and the lack of variety of the language features instructed on.

7.3.4.1 The quantity of LFEs

Considering the strong need for language support in this study, the low average time proportion of LFEs in the interaction time, 3.1%, seems rather limited. The lack of focus on form in this study, however, is very much in line with the findings about bilingual EMI teachers' classes in previous studies (e.g., Basturkmen & Shackleford, 2015; Costa, 2012; Llinares & Lyster, 2014; Lo, 2010; Pérez-Vidal, 2007), introduced in Section 2.3.4.4.3 of Chapter 2. In an EMI scenario similar to this study, Toth's (2018) work in a primary school in Sweden with monolingual EMI teachers also reported a lack of explicit teaching of language in EMI classes. Thus, it seems a lack of explicit instruction on language is a pattern that exits in both bilingual teachers' and monolingual teachers' EMI classes.

While explicit focus on language was found to be scarce in this study, the need for explicit language teaching is well documented (Crandall, 1987; Hoare, 2003; Lyster, 2007; Probyn, 2006), as elaborated in Section 2.3.4.4.1 in Chapter 2. Scholars have called for the need for content teachers to proactively plan their lessons to create opportunities for students to notice and pay explicit attention to language forms. This practice is argued to be particularly helpful to enhance students' L2 accuracy (De Oliveira & Schleppegrell, 2015; Lyster, 2007; Pérez-Vidal, 2007; Sherer et al., 2009; Swain, 1996). The scholars that developed Dialogic Teaching also highlighted the need of introducing necessary vocabulary and other language forms to facilitate students' substantial elaborations of their ideas (Alexander, 2004; Mercer & Littleton, 2007), as

mentioned in Section 2.3.2 of Chapter 2. Thus, the low quantity of LFEs in this study suggests an unfavorable condition for students' language learning in the EMI science classes. This lack of explicit support for language development could then deter students from participating in the classroom interaction and elaboration of their ideas, thus reducing their chances of benefiting from a constructivist learning environment.

7.3.4.2 The types of LFEs

Among different types of LFEs, a primary focus was found to be on non-technical vocabulary. Various aspects of non-technical vocabulary were instructed on, mostly in a pre-emptive manner, including meaning, pronunciation, and spelling. This shows that the non-technical vocabulary which is usually common to L1 students could potentially be problematic for EMI students. This could be due to the limited exposure EMI students typically have to English outside of the school context. Excerpt 19 in Section 4.1.10.3.1 in Chapter 4 provides a clear example. The surface literal meaning of the science concept *root* should not be challenging to EMI students at the high school level. However, a student asked for the meaning of the word *anchor*, a non-technical word contained in the teacher's explanation of *root*. Thus, this study provides further empirical evidence to support the argument proposed by Prophet & Towse (1999) and Clark (1997) that EMI science students tend to struggle with the general English and non-technical vocabulary that is typically known by L1 students, introduced in Section 2.3.4.4.2.2 of Chapter 2. This finding also answers the question raised in Section 2.3.4.4.2.2 as evidence is shown that the EMI students' problem with technical vocabulary could be often caused by the non-technical vocabulary contained in the explanation of the target technical vocabulary.

The primary focus on non-technical vocabulary also presents a contrasting finding with previous studies on bilingual EMI teachers. As mentioned in Section 2.3.4.4.3 of Chapter 2, both Basturkmen & Shackleford (2015) and Costa (2012) found a focus on explanation of technical vocabulary in EMI classes at the university level. One possible reason could be the level of educational phase, i.e., university vs secondary. This difference could also be because monolingual EMI teachers tend to use a wider range of non-technical everyday vocabulary and colloquial expressions, as compared to the bilingual EMI teachers. This speculation can find

support in Llurda's (2005) work that reported NS language teachers are often commented as having the advantage of possessing a larger vocabulary repertoire. Due to the lack of research on explicit instruction on language in EMI classes, more studies are needed to compare the types of LFEs in monolingual teachers' and bilingual teachers' classes.

The increased complexity of grammar in the texts for secondary school education (De Oliveira & Schleppegrell, 2015), as explained in Section 2.3.4.4.2.2 of Chapter 2, did not lead to a clear focus on grammar in the LFEs of this study. The only grammatical features instructed on was morphemes. This finding suggests a lack of support for students' development of academic literacy, where grammar plays a key role (De Oliveira & Schleppegrell, 2015; Schleppergrell et al., 2004). This could be because the monolingual EMI teachers lacked sufficient knowledge about grammar or awareness of the increased demand of grammar at the secondary school level. In comparison, Lo's (2010) work in Hong Kong found bilingual EMI teachers' explicit instruction on morphemes, verb tenses and part of speech. Again, this finding on grammar also echoes with the literature on NS vs NNS language teachers, where NS teachers are often commented on as lacking in grammar and linguistic awareness (Llurda, 2005; Moussu & Llurda, 2008).

As this study focuses on science subjects, the instruction on the features of the language of science, as explained in Section 2.3.4.4.2.1 of Chapter 2, were also important to consider. However, a lack of focus was found in the LFEs on the language structures that are common to the register of science, such as connectives to describe logical relationships, complex noun phrases and nominalization (Halliday, 1993). These features have been argued to be crucial to instruct on in secondary school content classes (De Oliveira & Schleppegrell, 2015; Gibbons, 2002). This finding, however, also aligns with the practice of bilingual EMI teachers (Basturkmen & Shackleford, 2015; Costa, 2012; Lo, 2010; Pérez-Vidal, 2007; Walker, 2011). Thus, it seems both bilingual and monolingual EMI teachers need to provide more instruction on the language structures commonly used in a subject domain.

7.3.4.3 The role of L1

The monolingual teacher sample in this study determined that the LFEs were conducted through L2-only. Thus, when a Chinese equivalent to an L2 word exists, the instruction had to be all through English. As Excerpt 19 in Section 4.1.10.3.1 in Chapter 4 showed, the teacher was not able to point out the Chinese equivalent of the target word *anchor*, '锚', nor would she know that the Chinese equivalent has the same original and figurative meaning as the English word. It could be argued that the L1 equivalent word would be more efficient for clarifying the meaning, and probably more effective for students to recall the word in the future (Zhao & Macaro, 2016), as compared to the two-minute-and-a-half explanation in L2. The amount of time it takes is an important factor to consider in EMI contexts where a balance between the teaching of content and language needs to be arrived at.

A counter argument could be that lengthy L2-only explanations provide students with more exposure to L2, particularly the non-academic kind. This is helpful for the EMI students as they probably are rarely exposed to non-academic English outside of the school context. In Excerpt 19, the teacher also used a variety of non-academic lexical items that are associated with *anchor*, such as *hold, in one spot, sink, float away, blow away* and so on. This rich description provides ample input and the detailed contextual information could help make the input comprehensible, which is a beneficial condition for second language acquisition (Krashen 1982). This incident also demonstrates the kind of negotiation of meaning which EMI classes are believed to provide for favorable L2 learning, where students need to comprehend teachers' input in L2 to understand the content knowledge (Cammarata & Haley, 2017; Dalton-Puffer & Smit, 2007).

The literature in the recent years has been seeing more recognition of the benefits of integrating students' L1, as particularly demonstrated in the line of work on translanguaging (García & Li, 2014). In EMI contexts, where L2 students face difficulties not only in understanding technical vocabulary but also often the non-technical ones, as discussed in Section 7.3.4.2 above, the L1 equivalent could be helpful in efficiently clarifying the meaning of a target word. This is particularly helpful considering the lexical density of science texts (Halliday & Martin, 1993), which was also mentioned as a key difficulty in the student interviews and questionnaires in this

study. At the same time, it also needs to be considered that L2-only explanations with ample details could provide students the much-needed exposure to non-academic English. As Joyce (2015) proposed, *'when the goal is primarily vocabulary expansion, the L1 method is preferable. On the other hand, for the purposes of general language development, learning through an L2 definition is favoured (p.225)'.*

7.4 Comparisons between the teacher beliefs and student beliefs about effective teaching of science and English in EMI science classes

The beliefs held by the teachers and the students about effective teaching of science and English in EMI science classes is another focus of this study. Discrepancies and similarities emerged between what the teachers believed and what the students believed. This section compares the teachers' beliefs and students' beliefs in terms of the role of interaction in both science and language learning, the role of practical activities, teacher language awareness (TLA), EMI science teachers' identity, and L1 use. Based on the significance argued in the literature of understanding the conflicts between teachers' and students' beliefs about effective teaching (Brown, 2009; Horwitz, 1990; Kern, 1995; Levine, 2003; Schulz, 1996), it is hoped that the discussion below could help to understand the obstacles there might be in creating favourable science and language learning environment in the EMI classes of this study.

Due to the small size of 15 for the teacher beliefs questionnaires collected, T-tests (or Mann Whitney U tests) were not run to compare the mean scores of teachers and students. The comparisons of the teachers' views and students' views are based on the discrepancies between the means and the distribution of the answers for each question items.

7.4.1 The role of interaction in science and language learning

The teachers in this study demonstrated consistently stronger recognition of the value of interaction for both science and language learning. However, both the teachers and the students showed less acknowledgement of the value of corrective feedback and substantial student output.

7.4.1.1 Teachers' stronger acknowledgement of interaction than the students

7.4.1.1.1 Science learning

Regarding science learning, the teachers demonstrated a stronger constructivist view than the students in all the subscales of the questionnaire. The teachers recognized more the importance of students' previous knowledge, students' output, teacher-student interaction, student-student interaction as well as the questions to promote higher-order thinking. When a more transmissionary approach was presented as an option, such as teachers' doing most of the talk vs. teacher-student interaction, the teachers still overall maintained a constructivist view while many students shifted to a more transmissionary voew. Thus, the teachers showed stronger resistance to the transmissionary approach than their students and demonstrated a firmer constructivist belief for science learning.

The findings from the interviews also confirmed these differences. The teachers frequently mentioned the use of interaction as an important strategy for facilitating students' science learning. Various input modification strategies and strategies of eliciting EMI students' output were also mentioned, such as breaking down general questions into smaller steps. These strategies demonstrated alignment with the socio-constructivist framework, where social collaboration is argued to be key in learning (Erdogan & Campbell, 2008; Gagnon & Collay, 2001; Prawat, 1992; Tobin, Briscoe, & Holman, 1990). The self-reported strategies of modifying input, breaking down questions and providing language items needed reflect the idea of scaffolding in Vygotsky's (1986) Sociocultural Theory, where it is argued that students can be aided by an expert or a more capable other to accomplish a task which would otherwise be difficult to accomplish by themselves.

Compared to the teachers' clear focus on interaction, the students valued more doing exercise as consolidation and comprehending teachers' input. They rarely mentioned the benefits of engaging in interaction with the teacher. The concern expressed by many students on how asking questions takes away lesson time which could be used on listening to the teacher also indicates that the students did not seem to see the process of communication and asking questions as a crucial part of learning. This suggests a lack of constructivist understanding of science learning (Prawat, 1992; Wellington & Ireson, 2008) and reflects the students' lack of awareness of the value of dialogues with the teacher for their learning of science (Mercer & Dawes, 2014; Mercer & Littleton, 2007; Mortimer & Scott, 2003).

7.4.1.1.2 Language learning

Regarding the role of interaction for L2 learning, while the students recognized the overall value of interaction for their language learning, their recognition was not as strong as their teachers. A wider spread of opinions was often observed among the students in their answers in the beliefs questionnaire, with sizable proportions of them having held unclear ideas about the benefits of interaction for their language learning. Similar to the results in the science domain, when more commitment and effort are required from the students, e.g., producing lengthy and regular output, the students were much less inclined than their teachers. Overall, the value of interaction for language learning did not seem to be deeply ingrained into the students' beliefs system.

A similar pattern also emerged from the interviews. In the interviews, the teachers also demonstrated more awareness of the use of interaction for promoting language learning, such as the use of various input modification strategies, the value of student output, and the need of providing language items needed for students to phrase their answers. These views are in line with Krashen's (1982) Input Hypothesis, Swain's (1985; 1995) Output Hypothesis, and negotiation of meaning (Gass & Mackey, 2006; Pica, Young, & Doughty, 1987; Pica, 1994). The attention to expand the students' vocabulary repertoire through introducing synonyms also indicates some teachers' awareness of integrating more opportunities for language learning through the learning of content ideas. The comments of exposing students to unknown language items and not limiting vocabulary use also demonstrate some teachers' awareness of the value

of the input that is slightly above the students' existing linguistic repertoire. This has been widely recognized as a favourable condition for L2 acquisition, termed as i+1, in Krashen's (1982) Input Hypothesis.

Compared with teachers' recognition of interaction, the students showed limited acknowledgement of the role of interaction for their language learning, particularly the role of output. Similar to their beliefs about science learning, they valued more the comprehension of the teachers' input than the production of their own output, and they also emphasized the value of doing ample practice questions for English learning. This again shows the high value placed on consolidations after class and practice. This finding also resonates with previous literature, where a focus on practice and consolidation instead of questioning was found among Chinese students (Arino et al., 2014). However, it also needs to be acknowledged that the kind of practice questions the students were referring to was not explored in this study. This limits the understanding of the kind of thinking process involved in doing ample practice questions, which may provide more information about students' beliefs.

The differences between teacher beliefs and student beliefs about English learning in EMI science classes are also reflected in their self-reported strategies of addressing the challenge of the high quantity of technical vocabulary. Lexical density indeed is identified as a feature of science texts (Fang, 2005; Halliday, 1993). In this study, the teachers emphasized the use of a variety of input modification strategies e.g., using simple vocabulary, synonyms, repetitions, visual aids and definitions of new technical vocabulary. On the contrary, the students showed clear reliance on looking for L1 translations themselves. They seldom mentioned engaging in negotiation of meaning with their teachers, such as asking teachers for clarifications and finding help from the teachers' modifications of the input. This difference again reflects the teachers' preference of using interaction and the students' lack of interest in engaging in interaction.

7.4.1.1.3 Explanations for classroom interaction

As teachers are often seen as the expert of pedagogy (Ariogul, Unal, & Onursal, 2009; Brown, 2009), these discrepancies described above are in a sense not surprising. However, the students' lack of interests in engaging with interaction with the teacher and producing output provide one reason for their limited participation in the teacher-whole class interaction.

The different levels of recognition of interaction from the teachers and students also indicate that the students might not have been fully aware of the value of certain effort from their teachers to engage them in interaction. Without being on board with their teachers, the students might not be enthusiastic about responding to the teachers' effort of eliciting output, as demonstrated by the short student turn lengths in the lessons. As few studies examined student beliefs about interaction for learning in the EMI literature, as mentioned in Section 2.6 in Chapter 2, and this study showed students' limited understanding of it, more research is needed to provide more evidence.

The different coping strategies for the high quantity of technical vocabulary also suggest that the students might not have appreciated the teachers' various input modifications as they were too busy looking up unknown vocabulary. The use of an electronic dictionary, although efficient, could lower their motivation to comprehend their teachers' modified input and negotiate meaning with their teachers, which have been argued to be a key mechanism of how interaction facilitates second language acquisition (Gass & Mackey, 2006; Long, 1996; Pica, 1994; Pica, Young, & Doughty, 1987; Pica, 1994). The lack of language-related student questions observed in the lessons also provides evidence to this interpretation.

The findings about the teacher beliefs also makes it possible to compare the teacher beliefs and their practice in the lessons observed. Consistencies between beliefs and practice were demonstrated in teachers' use of questions, including the high frequency of questions, a sizable

proportion of constructivist questioning approaches and a small proportion of recall questions. Thus, the teachers did put in effort to implement their constructivist beliefs. A clear inconsistency was in the use of group discussion. While the teachers clearly recognized the value of group discussion, the use of it was rather limited the lessons. One reason, given by some teachers, was that the students' use of L1 in their group discussion inhibited them from knowing if their students were on task and providing help. Thus, some teachers might have reduced the use of group discussion due to this language barrier.

The limited use of group discussion may present a conflict between what the teachers hoped for and the students hoped for. Similar to the teachers, the students also expressed strong recognition of the value of group discussion. However, unlikely teachers' worry about student use of L1 during group discussion, as explained above, the students clearly considered the possibility of speaking L1 to each other a main reason of needing group discussion. The lack of choice of using L1 with the monolingual teachers also pushed the students to value group discussion with peers more. This presents an area of pedagogical practice where some monolingual teachers may need to re-evaluate and take into consideration the students' needs.

In summary, this study made an initial attempt to understand what EMI teachers and students believed was effective teaching of subject content and English, particularly regarding the role of interaction, an area with little research done. The comparison between the teacher beliefs and student beliefs also provided possible explanations for the limited classroom interaction observed in this study.

7.4.1.2 Teachers' and students' less recognition of corrective feedback and substantial output

A pattern that emerged in both the teacher and student beliefs is the limited recognition of the need for corrective feedback to students' language errors, and students' substantial output.

7.4.1.2.1 Corrective feedback for students' language errors

The low recognition on the need of corrective feedback by the teachers and the students in the questionnaires and interviews indicates their limited awareness of the importance of feedback for students' L2 development. Corrective feedback is argued to be an important trigger for noticing, where students notice the gap between the target language and their interlanguage, leading to uptake and acquisition (Hanaoka, 2007; Schmidt, 1990). In the immersion contexts where language is believed to be learnt mostly incidentally, corrective feedback also plays an important part in enhancing students' accuracy in the target language (Llinares & Lyster, 2014; Lyster, 2007). Thus, the lesser degree of recognition on corrective feedback from the teachers and students in this study indicates they might have not paid sufficient attention to this particular component of interaction. In addition, considering many of the teachers had ESL/EFL training and teaching background, their lack of recognition of corrective feedback may also raise questions, which leads to the interpretation below.

An interpretation for this limited attention to corrective feedback is that the teachers and the students might have regarded corrections to language errors too language-oriented in their EMI science classes. As indicated by their relatively low recognition of EMI teachers as language teachers, they did not seem to consider the learning of English a priority in their science classes. Therefore, they expressed less hope for having corrective feedback to students' language errors. It is possible that if the teachers and students were asked about error correction in English language classes, their answers might have been different. Thus, the findings here only represent their views in the context of EMI classes and may not reflect their beliefs about language learning in general.

7.4.1.2.2 Students' lengthy output

While the teachers and the students acknowledged the general necessity of student output, less certainty was shown when it comes to students' substantial output. As elaborated in Section 2.3.2 of Chapter 2, students' substantial elaboration of their ideas is a key feature of Dialogic Teaching (Alexander, 2004; Littleton & Mercer, 2013; Mercer & Littleton, 2007). Producing lengthy and substantial output is also beneficial for language learning as it allows students more opportunities to test their hypotheses of more complicated and sophisticated language structures (Swain, 1985; 1995). Thus, this finding indicates an unfavourable belief for both science and language learning. It also suggests teachers' and students' lack of awareness of the rationale of the effectiveness of EMI for language learning, where it is believed that the opportunities of producing linguistically diverse and sophisticated output can be created during the learning of complex subject matter (Cammarata & Tedick, 2012; Nikula et al., 2013).

7.4.1.2.3 Explanations for classroom interaction

The teachers' and students' limited recognition for corrective feedback could explain the low quantity of language-focused episodes (LFEs) in the lessons. Although not all forms of corrective feedback involve explicit explanation of language structures, thus counted as LFEs, some forms of feedback do, such as metalinguistic clues (Havranek, 1999; Lyster & Saito, 2010; Mackey et al., 2003). Thus, the limited recognition of corrective feedback may have contributed to the limited LFEs in the lessons. In fact, few of the LFEs were teachers' reaction to the students' language errors during communication, which could possibly function as corrective feedback to student output. This again shows the alignment between the limited use of corrective feedback in the lessons and the limited recognition of it in the teachers' and students' beliefs system.

Similar to corrective feedback, the lack of belief on the value of student substantial output may also have contributed to the limited student output in the lessons. Although the students' lack of English proficiency is also an obvious factor, the teachers' lack of thorough recognition of student lengthy output could be a reason for the rare scaffolding in the lessons to help students

build complete and substantial answers and the rare requests from the teachers for full answers from the students. Likewise, the students' limited recognition of the value of lengthy output may also have contributed to their short and noun-oriented output in the lessons.

7.4.1.3 Interpretation of the students' beliefs about interaction

Although an interactive approach is widely argued to be beneficial for science and language learning, in this study the students' tendency of relying on in a transmissionary approach might be a pragmatic and survival strategy in an EMI environment. Considering the students' struggle with English, it is in a sense understandable that the students showed less resistance to the idea of listening to the teachers. While the language stood in the way of communicating science ideas, as admitted by most students, the students might feel they could learn more through receiving teachers' input to acquire knowledge about content and the language. While the students could not communicate much with the teacher and there were often misunderstandings, they might consider it more effective to just listen to the input first and then decode the input with the help of peers, dictionary and the internet through L1, which was commented as a key strategy by the students, shown in Section 6.5.3.1 of Chapter 6.

Another possible explanation for students' tendency of relying on teachers' lecturing is that they may have been culturally socialized into a more transmissionary teaching style in their previous Chinese medium instruction school experience (Gan, 2009; Zhang & Ding, 2013). This possibility was also explicitly mentioned by several teachers in their interviews. While teachers' beliefs are argued to be influenced by many factors, students' beliefs are often found to be influenced mainly by their learning context and culture (Nguyen, 2013). Therefore, it may not be surprising that the students in this study still preferred a teacher-led learning environment and lacked commitment of substantial participation. If the students were accustomed to a transmissionary teaching style before, they may not necessarily see it important to commit to the highly interactive and constructivist approach. Thus, the students' possible past learning experience with the transmissionary approach may explain their lack of thorough acknowledgement of the constructivist approach where substantial participation is required. Although the students did mention a learning environment to

foster critical thinking as a main motivation for attending a foreign high school program, which would require questioning and interaction with the teacher, their past learning experience might have influenced them to still have a tendency of relying on passive learning.

The solid science background knowledge that many students were commented on possessing might also have contributed to the students' lack of thorough belief about the value of interaction with teachers. Considering the students were not proficient yet in communicating science ideas in English with their monolingual teachers, they might have found group discussion with peers in L1 more helpful and thus held less strong beliefs about the value of engaging with their monolingual EMI teachers.

7.4.2 The role of practical activities

In the teacher beliefs questionnaire, all teachers agreed experiments is a way to reinforce the knowledge learnt, thus acknowledging a perspective in line with transmissionary view of using practical activities (Kang & Wallace, 2005; Tobin, 1986), and some also approved of the constructivist use of practical activities. In the interviews, the constructivist view was also seen, where some teachers argued that students should be encouraged to have their hypotheses and use experiments to explore possible results. While both views of labs have a place in teaching science and could benefit students' learning (Abrahams, 2010), as introduced in Section 2.3.2 of Chapter 2, the fact that some teachers only acknowledged the transmissionary use of lab suggests an unfavourable condition for teaching science in the EMI science classes in this aspect.

The students' beliefs also indicate they embraced both constructivist use and transmissionary use of practical activities. This undifferentiated belief could reflect their accurate understanding of the roles of practical activities, but could also be because that they did not have many opportunities to be exposed to practical work in their EMI science classes, as shown in the lesson observations. Therefore, they did not have a clear and informed view on the way practical activities should be used.

7.4.3 Teacher language awareness (TLA)

Teachers' self-reported TLA and the students' perceptions of their teachers' TLA are compared in this section.

7.4.3.1 Teachers' proficiency and knowledge about the target language

The students reported considerably less confidence in their teachers' proficiency of using the language of science, as compared to the teachers themselves. The obvious discrepancy indicates a possible unfavourable condition for students' language learning in EMI science classes as the teachers' satisfactory proficiency of the target language is vital for students' language learning (Andrews, 2007). However, this discrepancy is based on perceptions and may not accurately reflect the teachers' real proficiency of the language of science.

Most teachers and students believed that EMI science teachers need to have knowledge about English grammar and pronunciation, with grammar having received more recognition. However, the students demonstrated less confidence than their teachers on the teachers' knowledge about how the English language works. This suggests an unfavourable condition for English language learning in these EMI science classes. The speculation of the teachers' possible lack of knowledge about the English language, e.g., grammar, based on the findings of LFEs, also applies here.

One limitation of the findings above is the lack of clarify of the students' and teachers' exact understandings of the language of science and general English, i.e., what the language of science and general English meant to them. In the questionnaire, a short explanation was given after '*the language of science'*, which is '*the specific way of using language to talk about science*'. A short

explanation was also given after '*general English'*, which is *'not science-specific language'*. Due to the concern of the length of the questionnaire, no more details were given. Thus, it was possible that the teachers and students in this study had different interpretations. However, based on their comments in the interviews, it seemed both teachers and the students emphasized technical vocabulary as the main concern for the language of science, and no features of the science discourse beyond vocabulary were mentioned, e.g., nominalization, passive voice, the use of connectives. Regarding the teachers' and students' understanding of general English, in the interviews the teachers and the students also mainly focused on the issue of students' limited vocabulary repertoire. Thus, the data available shows that there was not a wide difference between the teachers' and the students' understandings of the language of science and general English. However, more exploration could certainly provide more clarity.

7.4.3.2 Teacher language awareness- difficult language areas

The teachers consistently showed stronger recognition of all the language areas that could be difficult for EMI students than their students. This indicates that the teachers were more aware of the possible areas of language difficulties EMI students face than the students themselves. The teachers also demonstrated stronger recognition of the need to know about the Chinese students' language difficulties. Again, the more favourable beliefs shown by the teachers are not surprising as the teachers are often considered the expert in teaching and learning (Brown, 2009; Nguyen, 2013). However, similar to the findings on interaction, common patterns also emerged in the teacher beliefs and the student beliefs. Both teachers and students considered instruction on the language of science more important than general English, and showed an unanimous interest in the instruction on vocabulary but not grammar.

Both the teachers and the students regarded it important to teach the language of science but less so regarding general English in the questionnaires. However in the interviews the difficulties general English caused were often mentioned. In fact, many students specified their low level of general English prohibited them from participating in interaction with the teacher. As shown in Chapter 6, evidence showing the importance of general English was also observed, where non-technical vocabulary (e.g., *ridge*) caused problems in students' comprehension of science

concepts (e.g., *magnetic stripping*). Several teachers also provided examples in their interviews about how non-technical vocabulary (e.g., *ramp*) inhibited students' understanding of science questions. Thus, the issue of general English was noticed by some students and teachers. This finding adds to the limited literature available on the challenges caused by non-science language for EMI science students, which are usually no obstacles for L1 students (Clark, 1997; Rollnick, 2000).

While several teachers noticed non-technical vocabulary was a problem, challenges were mentioned to predict the potentially difficult items for their Chinese students. This difficulty faced by some of the monolingual teachers in this study also echoes with the literature on native speaking language teachers vs non-native speaking language teachers, where native-speaking English language teachers are often described to be less competent than non-native speaking language teachers on understanding their students' difficulties (Andrews, 2007).

The more recognition of instruction on vocabulary than grammar is another common pattern found between the teachers and students. This stronger focus on vocabulary was also found in the past literature where CLIL teachers in Europe were reported to be more inclined to teach vocabulary than other linguistic aspects (Baecher, Farnsworth, & Ediger, 2014; Koopman, Skeet, de Graaff, & Graaff, 2014). This finding, again, may suggest the teachers' possible lack of awareness of the importance of grammar for science texts (De Oliveira & Schleppegrell, 2015; Halliday & Martin, 1993; Wellington & Osborne, 2001), and knoweldge about grammar. This indicates an unfavourable condition for the students' language development in the EMI science classes in this study.

A conflict emerged in the strong recognition of the language of science but limited recognition of grammar, as discussed in the two paragraphs above. Grammar is an integral part of the language of science (Halliday & Martin, 1993) and is a key component for developing academic literacy for secondary school students (De Oliveira & Schleppegrell, 2015; Wellington & Osborne, 2001). In addition, the communication of content knowledge could provide the

crucially meaningful context for the instruction of grammar (De Oliveira & Schleppegrell, 2015). However, both the teachers and students seemed to not have made the connection between the importance of instruction on grammar and the language of science. Thus, again, the teachers' and students' limited recognition of explicit instruction on grammar reveals that they might have not developed clear awareness of the important role grammar plays in the language of science.

Another explanation of the limited desire for explicit instruction on grammar is that the teachers and the students perhaps did not regard explicit instruction necessary in science classes. This speculation came from the fact that both teachers and students strongly hoped for teachers' modelling the appropriate way of using English to develop arguments and expressing ideas in science, but both expressed a low level of recognition of EMI teachers as language teachers. The appropriate way of developing arguments in science inevitably involves appropriate use of grammar. This indicates that both the teachers and the students perhaps preferred the learning of grammar structures implicitly through exposure in their science classes rather than explicitly through instruction. They might have regarded explicit instruction of grammar a task of their language teachers rather than science teachers.

7.4.3.3 Explanations for classroom interaction

The lack of consistency among the teachers and students on the importance of general English contrasts with the predominance of non-technical vocabulary in the language-focused episodes (LFEs) in the lessons. As presented in Chapter 4, non-technical vocabulary turned out to be the main type of language features addressed in LFEs. However, the problems general English could cause in students' comprehension of science explanations may not have been clearly and fully acknowledged by some teachers and students.

While a mismatch was found between beliefs and practice regarding general English, a match was found between the teachers' and students' lack of recognition of explicit instruction on grammar and the minimal presence of grammar-focused LFEs observed in the lessons. It seems

that both the teachers' and students' lack of regard of explicit instruction on grammar could be one reason for the limited focus on grammatical structures in the lessons, as neither of them put in substantial effort to initiate or signal the need of explanations of grammatical structures.

7.4.4 EMI teachers' role as a language teacher

While the results on TLA can already reveal the teachers' and students' limited recognition of EMI science teachers as language teachers, when being asked specifically about focusing on English language learning in EMI science classes, limited enthusiasm was shown on having English learning as a key focus in EMI science classes.

7.4.4.1 EMI science teachers as language teachers

Diverse views were shown on whether English should be a focus in their science lessons by both teachers and students. However, the teachers showed slightly stronger approval of their role as a language teacher than their students, thus showing a more favourable view for facilitating language learning in EMI science classes. The findings from the teacher interviews show that the teachers who were more inclined to take on the role of teaching English seemed to be motivated by their Chinese students' strong science knowledge but much weaker English proficiency.

Again, when it comes to the teaching of the language of science, both teachers and students clearly acknowledged the need of it. This indicates the teachers' and students' primary focus on content learning rather than language learning, as the teaching of the language of science is more closely related to content knowledge learning. A similar subject matter motivated attitude of language learning was also found in Macaro, Akincioglu, & Dearden's (2016) study with EMI lecturers in universities in Turkey.

An issue that received particularly low interest from the students is the need of including English language learning goals in lesson objectives, where a small majority of the teachers in fact approved of it. This gap indicates that, at least at the belief level, the students might resist having language learning objectives as part of the lesson objectives if some teachers are to do so. Although in the pre-lesson interviews, none of the teachers actually mentioned language learning objectives, indicating an absence of actual implementation of this belief, the gap between the teachers' and their students' beliefs on this issue suggests a potential obstacle for promoting students' English language learning in EMI science classes.

With references to the findings in previous studies, the teachers' limited identifications of themselves as language teachers in this study is not a unique case. For example, in the CLIL programs, despite the clear goal of integrating language and content learning (Fortune et al., 2008), teachers were often found to only see themselves as content teachers (Airey, 2012; Tan, 2011). This view was also found with EMI teachers in Hong Kong (Lo, 2017; Trent, 2010), as mentioned in Section 2.5.4.2 in Chapter 2. Thus, this study shows that the monolingual teachers in this study also lacked clear recognition of themselves as language teachers, like the bilingual EMI/CLIL teachers in previous studies.

Additional gravity of the issue of EMI teachers' identity is also revealed in this study. While the finding on teachers' identity regarding language teaching is not new, what is new in this study is the evidence of teachers' clear awareness of certain areas of L2 pedagogy, e.g., the role of interaction, and strong concerns for their students' English learning. However, with all this evidence, the teachers still had limited recognition of their responsibility to teach language in EMI science classes. The finding here, thus, is very persuasive and telling in that the EMI teachers' perception of their role may be a deep-rooted one and difficult to change. It also suggests that even when some EMI teachers have already developed a level of knowledge about language pedagogy and have clear recognition of the importance of helping students improve their English, they may still not fully recognize that it is their responsibility to systematically and consistently integrate the teaching of different language areas into their lessons.

What is also new evidence in this study is students' views on the issue of EMI teachers' identity, which is rarely researched in the past literature. This study shows that students in EMI classes may even have less desire to see their content teachers as language teachers and may be even less inclined to focus on English learning in their content classes, apart from the learning of the language of science. A primary focus on the learning of subject knowledge also emerged. However, the students did not seem to have made the linkage between the development of their English proficiency in EMI science classes and their effective subject knowledge learning. Successful communication about science ideas with teachers, a key condition for effective science learning (Alexander, 2004; Jenkins, 2000; Kawalkar & Vijapurkar, 2013; Littleton & Mercer, 2013), is dependent on students' sufficient mastery of English. In this study, lack of English proficiency was indeed a key reason identified by the students for the lack of communication with their teachers. Thus, the students' belief on EMI teachers' identity indicates not only an unfavourable condition for their language development, but also bears a possible negative influence on their subject knowledge learning.

7.4.4.2 Explanation for classroom interaction

The limited identification of EMI science teachers as language teachers by both the teachers and the students could explain the low proportion of language-focused episodes (LFEs) observed in the lessons. Considering the discussion made in Section 7.4.3 earlier and this section, the teachers and students seemed to hope to improve their English proficiency but preferred it to take place implicitly through teacher modelling and the exposure of the language rather than explicit instruction, correction of errors and teachers' purposeful lesson planning to integrate language learning objectives. Although in the literature it is widely argued that in bilingual programs the learning of the L2 largely takes place incidentally through communication about the subject matter (Cammarata & Haley, 2017; Klaassen & De Graaff, 2001; Lazatuk, 2007; Salomone, 1992; Sylvén, 2013; Walker & Tedick, 2000), scholars have been increasingly calling for a need of systematic and purposeful integration of instruction of language in the subject lessons to better facilitate students' L2 development (Costa, 2012; Long & Robinson, 1998; Norris & Ortega, 2000; Pérez-Vidal, 2007; Spada & Tomita, 2010). Thus, in this study, the teachers' and students'

overall limited acknowledgement of EMI teachers as language teachers indicates an unfavourable condition for language learning in their EMI science classes and this belief is also reflected in the limited LFEs in the lessons.

7.4.5 The use of L1

As the monolingual teacher population constitutes a key distinctive feature of the EMI scenario in this study, the teachers' and students' views on monolingual versus bilingual EMI teachers can bring interesting insights. In this study, different views were found between the teachers and students, with the students having a strong need for bilingual teachers who can provide L1 translations, and the teachers being split on this issue.

The students' reasons for the strong reliance on L1 showed their primary concern for learning science knowledge. In contrast, the reasons given by the teachers who disapproved the use of L1 showed these teachers' main concern for the students' L2 learning, where an L2-only immersion environment was believed to be the best. This seems to contrast with their limited recognition of themselves as language teachers, discussed in Section 7.4.4 above. Some teachers' two different attitudes suggest that on the one hand the teachers did recognize language learning as a concern, but on the other hand they probably preferred facilitating students' language learning through communication and implicit learning and did not see it their duty to provide explicit instruction on language. The prospect of students studying in an English-speaking country for tertiary education also emerged as a key reason in their support of an L2 only environment.

Although the reason behind some teachers' support of an L2-only environment was for more effective L2 learning, the obvious difficulties the students had to engage effectively in interaction with their teachers shows that such a view does not necessarily favour the students' L2 development. It may also deter the students' science learning. If students are not producing output and interacting with the teachers, opportunities are reduced for language development

(Long, 1996). Similarly, the constructivist teaching approach of science is also centred around students' participation (Jenkins, 2000). Without much participation, the constructivist teaching approach is compromised. Thus, some teachers' support of an all-English immersion environment shows that they might not have realized the conflict between their view on L1 use and effective learning of science and language.

This view of favouring a monolingual approach by some teachers in this study, however, is not a unique case. Discouragement of mixing between L1 and L2 is seen in many bilingual programs around the world. For example, the original model for bilingual education, the French immersion programs in Canada, had a long tradition of separating students' L1 and L2 in instructional time and translation between L1 and L2 was discouraged (Cummins, 2014). Similarly, the monolingual model has also been promoted in EMI programs in Colombia (Belhiah et al., 2013), South Korea (Kang, 2007), and Hong Kong (Swain, Kirkpatrick, & Cummnins, 2011). Studies investigating teachers' views have also often found that EMI teachers, mostly bilingual teachers, are in favour of a monolingual approach and regard teachers' use of L1 a deficiency of students' L2 learning (Galloway et al., 2017; Paulsrud, 2016). Thus, the disapproval of L1 use by half of the monolingual teachers in this study are in line with many previous studies, although the bilingual EMI teachers can use their students' L1 and the monolingual teachers cannot.

The other half teachers' preference of a bilingual approach in this study, however, is more in tune with the growing acknowledgment of the facilitative role L1 plays in language education and EMI education in the recent literature. This was discussed in Section 2.4.1 in Chapter 2 Literature Review. The integration of students' L1 can also find support in the recent development of the concept of translanguaging. It argues that students' L1 is an integral part of their linguistic repertoire and is used in students' meaning making (García & Li, 2014). The recognition given by some teachers in this study demonstrates their awareness of the benefits L1 could bring, although they themselves could not use it in their teaching. The comments of how forbidding students' L1 use would mean students not speaking about their ideas at all also demonstrates some teachers' awareness of the restrains the language difficulty posed on the constructivist teaching approach in this EMI context.

A similar spread of views on L1 was also found in Toth's (2018) study with monolingual EMI teachers in a primary school in Sweden. Some foreign monolingual teachers, as Toth reported, were worried that reliance on L1, Swedish, could be a constraint for students' L2 development. Others, however, regarded L1 as an important means of support in peer interaction for aiding meaning making where more competent students could explain difficult concepts in Swedish to their classmates. These diverse views coincide with the division of views held by the monolingual EMI teachers in this current study. These findings together show that L1 use may be a controversial issue among the monolingual EMI teachers and the teachers may hold different views on whether L1 should be used by students.

In contrast with the teachers' divided views, the students expressed a strong hope for L1. The reasons for knowing the L1 translations to access prior knowledge learnt through L1 and their everyday experience could be explained by the research findings in SLA where prior knowledge of the topic of the input is argued to play an important role in students' listening comprehension, on top of their actual language proficiency level (Macaro, Graham et al., 2016). Sound knowledge of the topic area can help students overcome deficiencies in linguistic knowledge (Macaro, 2018). These findings are also particularly relevant to this study as the students' language difficulties were reported and observed to be an obstacle for students' listening comprehension. In addition, they were commented as having solid science knowledge. Thus, access to prior knowledge is particularly helpful in this context and can provide the much needed support with the students' overall listening comprehension in EMI science classes. In this sense, it is understandable that the students reported a strong need for knowing L1 equivalents and the practice of looking up L1 translations before, during and after classes.

An additional reason for the students' strong need of L1 in this study could be the way some technical vocabulary items are presented in Mandarin, which may provide a clearer breakdown of the science concept behind it than the English terminologies. This speculation came from the example, '*biome*', which is the topic of Kate's two lessons. The Chinese equivalent of biome is

‘生态系统’ (eco-system). The first two characters, 生态, in the Chinese equivalent mean *eco* and the last two characters, 系统, mean *system*. This way the meaning of ‘*biome*’ is clearly demonstrated. Thus, in some cases knowing the L1 equivalent of certain technical vocabulary may in fact provide another resource for understanding the science concepts, and this may also be a factor in the students’ hope for knowing the L1 equivalents.

The students’ strong need for L1 found in this study has also been identified in other EMI contexts. In Ellili-Cherif & Alkhateeb’s (2015) study, conducted in higher education in Qatar, students expressed the need of using L1, Arabic, for more effective content learning. Strong preference of L1 was also found in Tarhan’s (2003) study with EMI science students in secondary schools in Turkey where most students regarded L1 instruction more effective. Similarly, Tun, Lam, and Tsang (1997) in a large-scale study (N=5000) of lower-secondary school students in Hong Kong found that the majority of the students reported that they would save a lot of time studying all subjects in Chinese and that some use of Chinese was essential in an EMI class. While the students in this current study and in these previous studies acknowledged the benefit of EMI for improving their English proficiency, they also expressed a clear preference of L1. Thus, this study with monolingual teachers adds to the existing findings in the literature regarding the difficulties an L2 only instruction environment brings for EMI students’ content learning and the students’ clear hope for L1 as an aid.

In summary, while the previous literature explored the teachers’ views and students’ views of L1 use, often separately, this study compared the two in the same context and found various reasons for approving and disapproving L1 use. Different views emerged between the teachers and students. It seems a more flexible approach of the medium of instruction may be helpful, at least as a strategy for the transitional period where the students are still catching up with their English proficiency.

7.5 Difficulties of implementing a constructivist approach and creating favourable conditions for L2 learning in EMI classes

This study provides a unique and rare opportunity to observe the use of classroom interaction in authentic EMI classes in the sense that the teachers do not switch to L1 due to deficiency of their L2. Despite the teachers' high English proficiency and their clear belief about the role of interaction for science and language learning, limited classroom interaction was still observed. This means other factors were prohibiting the implementation of a constructivist approach and creation of favourable conditions for L2 learning in this EMI context. This section draws on the findings of teachers' background, the discrepancies between the teachers' and students' beliefs and the classroom interaction behaviour to discuss the possible factors that might have contributed to the difficulties of using classroom interaction.

7.5.1 Teachers' background

One factor that led to the limited classroom interaction could be that most of the teachers were rather young and inexperienced. For novice science teachers, the implementation of constructivist teaching practices could be challenging even in L1 science classes (Gallagher, 1991; Hashweh, 1996b). Thus, with the additional challenge of teaching L2 students from a different cultural background, it is understandable that the implementation of the constructivist approach could be considerably challenging. In addition, four teachers in this study did not have any science training background, which may also have put restrains on aspects of the use of interaction to promote students' participation and productive thinking.

Another possible factor is that none of the teachers had any training on EMI or content-language integrated pedagogy. This may have limited the use of the opportunities in their EMI classes to integrate development of students' L2 competence. This also in turn influences the students' communication of science ideas as language is the tool of communication. However, EMI/CLIL teacher training is still at the developmental stage worldwide and many previous studies have also identified that subject teachers do not have any specific training on EMI pedagogy (An & Murphy, 2018; Lasagabaster & Ruiz de Zarobe, 2010; Lo, 2017). This study adds to the existing

findings and shows the strong need for EMI teacher training programs as this study reveals teachers' high English proficiency alone is not enough.

7.5.2 Teachers' beliefs and students' beliefs: interaction, TLA, EMI teachers' identity, the use of L1

As discussed in Section 7.4 above, discrepancies emerged between the teachers' and students' beliefs about science and language teaching in EMI science classes. This also led to explanations about aspects of the classroom interaction behaviour in the lessons. Only a brief summary is provided here.

Classroom learning is not unilaterally decided by the teacher, the students also make their decisions about how to achieve their learning goals (Woods, 1997). A sizable proportion of the students in this study had limited awareness of the value of interaction for science learning and language learning in EMI contexts, which may be a reason for their limited participation of classroom interaction. Other factors also include both teachers' and students' limited acknowledgement of the value of students' lengthy output for science and language learning. This may also explain the prevailing short answers from the students.

Certain beliefs regarding language learning could have also contributed to the difficulties of using interaction and creating a favourable language learning environment in this study. These beliefs include the both the teachers' and students' limited identification of EMI teachers as language teachers, the lack of awareness of the challenges general English could cause, and the limited acknowledgement of the need of explicit instruction on grammar by both the teachers and students. These unfavourable beliefs about language learning also mean unfavourable conditions for facilitating classroom interaction as students need to develop their L2 to be able to engage in interaction.

The difficulties mentioned by many teachers of predicting their students' language problems, particularly regarding non-technical vocabulary, may also be another factor. Teachers' understanding of their students' language needs is essential for providing pre-modifications of input (Ellis & He, 1999; Mackey, 1999), modifications of input during negotiation of meaning (Pica, 1994), and corrective feedback (Lyster & Ranta, 1997). Thus, this difficulty may prohibit the teachers' use of these mechanisms in interaction. The problem with non-technical vocabulary also means it is difficult for the teachers to provide either planned or spontaneous explicit instruction on non-technical vocabulary (Lyster, 2007). While technical vocabulary is likely to be listed in a glossary in a textbook, the scope of non-technical vocabulary is simply too wide and thus the problematic ones may be hard to locate and identify for the foreign monolingual teachers.

The students' reliance on L1 also reflects their preference of looking for answers themselves rather than engaging with the teachers in classroom interaction. This could stem from the students' rather limited English proficiency to communicate effectively with the monolingual teachers. The monolingual teachers' inability of using L1 to facilitate students' access to prior knowledge and everyday experience in L1 may also have pushed the students to rely on themselves to make sense of the new content. In addition, the culture of learning the students were possibly socialized into and their past learning experience with a possibly more transmissionary approach may also have contributed to their limited recognition of the constructivist approach and their lack of participation in classroom interaction with the monolingual teachers.

7.5.3 Students' L2 proficiency

The significant issue of students' low L2 proficiency was recognized by both the teachers and students and was reflected in classroom interaction as an important factor that prohibited students' participation in classroom interaction. This theme was also consistently reflected in the student interviews, from their special appreciation of their teachers' use of visual aids and provision of the written form of terminologies to their hope for more pauses in the teachers' talking and more

time allowed for group discussion. Similarly, this issue was also frequently mentioned in the teacher interviews, from the perceived effective strategies for facilitating science learning to the difficulties of using practical activities.

What is contrasting to the students' limited L2 proficiency is that both teachers and students had limited recognition of EMI teachers as language teachers and of the need to focus on English language in their EMI classes. This indicates that the teachers and students may need to develop more awareness of the importance of language and communication for learning science, where the development of language can also benefit their science learning (Lemke, 1990). They also need to be more aware of the opportunities EMI classes can provide for language learning within the meaningful context of learning subject knowledge (Cammarata & Haley, 2017; De Oliveira & Schleppegrell, 2015).

7.5.4 Other contextual factors

As mentioned in Section 2.5.3 in Chapter 2 Literature Review, previous studies have identified that although the beliefs teachers hold make a crucial impact on their teaching behaviour, contextual factors play a part in the translation of the beliefs into actual practice (Mansour, 2010; Pajares, 1992; Woods, 1996). The same was also found in this study, where in the teacher interviews various contextual factors were mentioned to have inhibited the teachers from enacting their beliefs about the use of interaction. Some of the contextual factors are already mentioned above, including the students' limited L2 proficiency, and the students' tendency of relying on teachers' lecturing. Other factors that were mentioned by the teachers include an admission process where students' English proficiency was not screened strictly enough, the lack of lab facilities, and the time constrains due to the need to teach the subject content knowledge in the curriculum when the students have language difficulties.

7.6 Limitations

This section provides a summary of the limitations that rose from the research methodology.

7.6.1 Samples

There is a lack of evidence of the actual academic profile of the student sample. Together with the lack of official documentation about the academic performance of the foreign high school programs in China, it is hard to estimate the degree to which the student sample represents the target student population.

Lower difficulty levels and grade levels are more represented in the lesson sample. As Stodolsky (1990) specified, the subject matter, instructional activities, the learning objectives and the grade level could all be factors that cause systematic variation in teachers' teaching behaviour. Thus, the unbalanced representation of the difficulty levels and the grade levels of the lessons in this study could mean limitations in presenting objectively the teachers' use of classroom interaction in their EMI science classes. As some teachers commented, it was more difficult to interact with lower grade level classes. This means the classroom interaction observed may represent more the difficult situations of using classroom interaction. In addition, Biology lessons and British Columbia Canadian curriculum were also more represented in the lesson sample. This may have in some way skewed the classroom interaction behaviour observed. However, more evidence is needed to verify this speculation.

The observation of only two lessons for one teacher may be limited in capturing a teacher's ordinary teaching behaviour. However, in most of the cases the teachers demonstrated similar behaviour between their two lessons. The occasional cases where the two lessons had drastic differences were mostly due to the vastly different use of instructional activities, such as heavy use of non-whole-class interaction activities. The students' comments in the post-lesson interviews also confirmed that in most of the lessons the teachers' behaviour could represent their typical teaching behaviour.

Despite all the limitations mentioned above, the lessons were united by a clear consistent teacher-dominated pattern. This suggests a certain level of validity of the data in capturing the classroom interaction behaviour between monolingual teachers and Chinese students in foreign high school programs in China.

7.6.2 Elicitation of beliefs

Video stimulated recalls with clips of the lessons shown could have elicited richer reflections from the teachers and students on certain behaviours in the lessons observed (Borg, 2006). However, they were not used in this study because of the limited time gap between the lesson observations and the post-lesson interviews. To make use of the lesson observed to elicit richer answers, incidents and examples from the lessons were actively asked for. The effort of conducting the post-lesson interviews as soon as possible after the lesson observations was also to ensure fresh memory of the lesson experience.

7.6.3 Analysis of classroom interaction

Several limitations exist in the analysis of the lesson observation data.

7.6.3.1 Paralinguistic features

In the lesson observations, the camera was set at the back of the classrooms and certain paralinguistic behaviours from the students, particularly those sitting at the back of the classrooms, might not have been captured. Certain paralinguistic features (e.g. shaking head, nodding, confused look etc.) could bear meaning in the teacher-student interaction and certain utterances from the teacher might have been the result of such behaviours.

Teacher nomination is one parameter that could have been compromised due to the missing of students' paralinguistic features. The students who were nominated by the teacher could have indicated their wish to answer with their paralinguistic features, such as a nod. In these cases,

the students were not actually nominated but volunteered themselves. Thus, the benefits of teacher nominations do not really apply.

7.6.3.2 Private conversations

As the lesson videos show, there were often discussions among the students themselves and private conservations between the teacher and individual students, for example, during self-practice time. These private conversations could also form an important part of students' learning in EMI science lessons. The features of the teacher-individual student interaction, e.g., the quantity and quality of student output, might be different from teacher-whole class interaction. However, these incidents of interaction were not explored.

7.6.3.3 Videos

The use of videos emerged as a rather common practice. They were used as a part of the teaching of the science content and were commented as a useful strategy by both the teachers and students. However, only the time proportion of the use of video was provided and the actual content and the language used in the videos were not explored. The content of it might have had an influence on the teacher talk, including the science ideas explained and the use of the language, which may also impact the student talk elicited. This aspect was not considered in the analysis of the classroom interaction, which constitutes another limitation.

7.6.3.4 Lab work and group discussion

Similar to the videos, in this study lab work and group discussion were only explored quantitatively in the mapping of the use of instructional activities in the lessons. However, the contexts in which these activities took place and how they were used to fulfil the lesson objectives were not explored. The use of lab activities and group discussion do not necessarily mean they contributed to a constructivist classroom (Abrahams, 2011; Hohenstein & Manning,

2010; Jenkins, 2000), and thus the quantitative results only allowed a simplistic understanding of the use of these activities.

7.6.4 Analysis of the teachers' and students' questionnaires and interviews

As pointed out earlier, the teachers' and students' exact understanding and interpretation of *the language of science, general English* and *grammar* were not clear in this study. Considering the length of the questionnaires, only simple definitions were provided– e.g., '*the specific way of using language to talk about science*' given for the language of science, and ' *not science-specific language'* for general English. Conflicting views were in fact observed in students' answers in the questionnaire and the interviews regarding their difficulties with *the language of science, general English* and *grammar*. More accurate understandings of the teachers' and students' understandings of these terms are needed.

7.7 Contribution to knowledge and conclusion

This section first briefly reiterates the areas of contribution to knowledge this study makes, corresponding to the statements made in Chapter 2 Literature Review. Then, it summarizes the key arguments in this study, which brings new understandings of key pedagogical issues in EMI.

7.7.1 Areas of contribution to knowledge

This study took an initial attempt to explore a newly emerging EMI context of foreign high school programs in China, featuring monolingual EMI teachers who cannot use students' L1 in their teaching but possess a high level of English proficiency. This is a rather unique and rarely explored EMI scenario as most existing EMI literature features bilingual teachers who share the same L1 as the students. The monolingual teacher population ensured that classroom interaction

was unlikely to be constrained by the teachers' own lack of L2 proficiency, but L1 was not at the teachers' disposal should they wish to use it. This provided a valuable opportunity to observe how content is taught in L2 only as inferred through classroom interaction in such environment.

To explore this distinctive EMI scenario with monolingual teachers, an interdisciplinary approach was adopted, drawing upon expertise in both language education and in science education. A fairly large sample of 30 lessons was collected. The use of a high number of classes to investigate both content learning and language learning is rather scarce in the existing classroom-based EMI literature.

A fine-grained analysis of the classroom observation data produced both quantitative and qualitative findings of 12 parameters of classroom interaction, enabling a comprehensive understanding of the classroom interaction behaviour. The student output was explored in terms of both quantity and quality, indicated by the noun verb ratio. The use of Chin's (2007) framework of teacher constructivist questioning approaches in science classes allowed a detailed analysis of the EMI teachers' effort of promoting science subject matter learning. The analysis of student questions provided understandings of this under-researched but significant area in EMI classes. Responding to the call for more research on the explicit instruction on language in EMI classes, this study also moved forward the discussion through providing quantified results on the extent to which explicit instruction on language was conducted as well as the types of linguistic features addressed. The findings of various aspects of classroom interaction which has been argued to be significant for science learning and language learning in the literature led to a rather comprehensive understanding of both content and language learning in the lessons in this study.

The strength of the investigation of classroom interaction in this study lies in the consideration of multiple aspects of it. Different parameters may influence each other and connections among different parameters were made, such as the linkage among teachers' use of wait time, teacher questions, and the student talk. The understanding of a wide range of aspects of classroom

interaction increased the validity of the implications drawn regarding the learning of science and language in this scenario with monolingual teachers.

Another key area of contribution to knowledge is the exploration of both the teachers' and students' beliefs about effective teaching of science and language in EMI science classes, which then allowed comparison between the two. Previous literature has mainly explored stakeholders' attitudes and perceptions of EMI programs, but rarely touched upon their beliefs about pedagogical issues. However, what teachers and students believe is effective teaching of subject matter and English in EMI classes bears a direct influence on pedagogical practices. In this study, findings about the teachers' beliefs and the students' beliefs allowed speculations of the possible reasons of the classroom interaction behaviours observed. The understanding of the students' beliefs, which is particularly under-researched in the EMI literature, also provided particularly crucial feedback to the classroom practices in these EMI classes. Because of the widely discussed role interaction plays in EMI classes to allow more effective L2 development, the exploration of teachers' and students' beliefs about this issue also bears particularly important meaning.

In the end, the connections made across classroom interaction, teachers' beliefs and students' beliefs in this study provided multiple perspectives to understand the teaching and learning in this EMI context with monolingual teachers. The beliefs held by the teachers and the students provided explanations of the classroom interaction observed, and the classroom interaction also sometimes confirmed the beliefs held by the teachers and the students and other times revealed the difficulties of realizing the way of teaching that was believed in.

7.7.2 Summary of the key arguments of this study

The findings of this study suggest that teachers' high English proficiency alone is not enough to ensure a high level of classroom interaction in EMI science classes. Limited classroom interaction still persisted, featuring strong teacher dominance and limited student output both in

terms of quantity and quality. While in the past literature the bilingual EMI teachers have often been observed to close down classroom interaction with students and reduce discussion on complicated subject matter, this study shows that even though the teachers themselves possess a high level of English proficiency, it is still difficult to involve student participation and promote extensive discussion of subject matter in EMI science classes. The classroom observation, questionnaires and interviews provided several explanations for this.

One reason for the limited use of classroom interaction could be that the teachers, although possessing a high level of English, still lacked EMI pedagogy, such as the use of a wide range of constructivist questioning approaches, sufficient use of wait time and teacher nominations, scaffolding the students' responses, provision of explicit instruction on language, particularly grammar, and so on. This could be due to their lack of training on EMI and content-language integrated pedagogy. The teachers' own limited teaching experience, as many of them were rather young teachers, could also be another factor. Reasons could also be found from the student aspect. The students' limited L2 proficiency to comprehend input and accurately phrase their ideas, beliefs that do not thoroughly align with the constructivist teaching approach, and reliance on L1 translations were also factors that possibly contributed to their lack of engagement with their teachers in class. With all these factors in the background, the teachers' inability of using L1 to facilitate classroom interaction, such as providing the L1 equivalents of new technical terms and making connections with students' prior knowledge and everyday experience, might have further deterred the students from communicating with their monolingual teachers. As a result, most of the students said they preferred having a bilingual science teacher, or a monolingual science teacher with a bilingual teaching assistant.

The findings of this study suggest that, when the EMI teachers possess high English proficiency, the students' own L2 proficiency level and the alignment of their beliefs with their teachers' beliefs also have important roles to play in creating an interactive EMI classroom. In addition, the findings about the teachers' and students' beliefs about language learning in EMI science classes in particular also revealed several issues which could limit students' participation in classroom interaction.

First, despite the foreign programs' pragmatic goal of preparing students to study overseas and the students' obvious struggle with the L2, the teachers and the students were still reluctant to recognize EMI teachers as language teachers. What was particularly under-valued was explicit instruction on grammar. However, grammar is an integral component for students' English proficiency and is inevitably needed for students to compose their answers and communicate effectively with their teachers. In addition, the important role non-technical vocabulary plays in students' comprehension of science explanations also lacked consistent and clear recognition from the teachers and students. Thus, to better facilitate students' L2 development in the EMI science classes, it seems both the teachers and students need to develop a more comprehensive understanding of the language areas that could be difficult to EMI students, which are not limited to technical vocabulary, as the classroom observations showed in this study. They also need to recognize EMI teachers' role to systematically integrate language learning into content classes, not only through implicit language learning opportunities in the communication of content but also through explicit instruction on a wide range of language features.

The common background in ESL/EFL that many monolingual teachers had also provided evidence that the conventional ESL/EFL training and teaching experience may not be sufficient to prepare teachers for EMI contexts. Despite the background with ESL/EFL training, the teachers in this study still faced significant challenges of sustaining classroom interaction, putting across complex subject content, and integrating language development opportunities. The teachers' lack of thorough understanding of the roles that feedback and students' substantial output play for language learning in EMI classes also revealed an important area to address in EMI training.

As this study examines a rare EMI scenario where L1 could not be used by the teachers, the evidence from this study provides an interesting angle to understand the role of L1 in EMI classes. Without the use of L1, despite the teachers' high proficiency in English, difficulties were observed for the teachers and the students to put across their messages through L2 only and the

students commented that they were deterred from engaging in communication with their teachers. The students were also found to often rely on using bilingual dictionary and asking peers in L1 to solve problems. Considering the key role of student participation in social constructivism, without much student talk it is hard to build a favourable environment for science learning. Some teachers' disapproval of L1 use also indicated their lack of awareness of how students' language difficulty could stand in the way of implementing a constructivist teaching approach.

In the end, it needs to be noted that the implications drawn on the opportunities for science learning and language learning in the lessons in this study were based on the theories, hypotheses and pedagogy frameworks developed in the past literature. No hard evidence was available in this study on the students' actual learning outcome. Thus, whether a low level of classroom interaction does lead to low academic attainment is unknown. It could be possible that the students' preference of listening to the teachers in this study was a survival strategy for them in a new EMI environment when they did not have the linguistic resources to interact with the teachers through L2 only. The students might have felt that they could learn more about the appropriate and accurate ways of phrasing science ideas in English and more science content through listening, as compared to having limited communication with their teachers. Their reliance on looking for L1 translations and discussing among peers in L1 might also reflect their strategy of receiving input in L2 first and digesting the content with the help of L1 afterwards. Considering the students' low L2 proficiency, limited experience with EMI education, and possible past learning experience with a transmissionary approach, questions are raised in this study as to whether a constructivist approach with ample interaction is in fact a more effective way to facilitate learning.

7.8 Implications for pedagogy and future research

Based on the findings of this study, the following sections provide the implications for teaching and learning, and directions of future research.

7.8.1 Implications for pedagogy

Findings about multiple aspects of classroom interaction in this study revealed the difficulties of moving dialogues forward with students in EMI science classes, despite the teachers possessing high English proficiency. The first pedagogical implication from this study is that EMI teachers need to recognize that the conversation with L2 students to discuss subject matter takes more time and effort, including frequent use of repetitions and reformulations of questions, the time needed for students to formulate and articulate their questions and answers fully, and incidents of negotiation of meaning about language items that could be intertwined with the discussion of subject matter.

To facilitate classroom interaction and promote a constructivist learning environment, EMI teachers are advised to consider more generous use of wait time after a question and wait time after a student's response, more use of teacher nominations, more pauses in their talk, and giving students more time to finish their utterances during interaction. More group discussion time may also be particularly helpful when the students already possess a certain level of subject knowledge background but struggle with the L2. The use of diagrams, drawing and other visual aids, which provide the spelling of key terminologies, have also been identified as particularly helpful to aid students' comprehension in this study.

In terms of the language development aspect, more effort for explicit instruction on language is needed, and a wider range of language aspects need to be addressed, particularly grammar. This may require a more systematic and thorough understanding of the features of the language of science beyond the vocabulary level from the teachers, and identification of these features in the use of language in each lesson. Apart from the explicit teaching of language, findings of this study also showed the need of addressing the EMI subject teachers' beliefs about certain

aspects of the use of interaction, including the value of students' lengthy output, the value of teachers' corrective feedback to students' language errors. The possible difficult areas of language for EMI students is another area that EMI teachers need to develop awareness of. As EMI subject teachers are often content specialists and not language specialists, EMI teachers may benefit from explicit clarifications of these issues. In addition, the rationale of the believed benefits of EMI for language development, which is partly built upon the role interaction plays for language learning, may also need to be specifically addressed to the teachers for them to recognize certain issues in the use of interaction, such as the importance of requiring and scaffolding students' full answers. Through recognizing the ample explicit and implicit language learning opportunities that could be created in EMI classes, EMI teachers may become more inclined to recognize themselves as language teachers.

Teachers' use of questions is another area that needs to be improved. Special effort is needed in widening the range of constructivist questioning approaches, and scaffolding students' answers to these questions. To enable effective use of a wide range of questions, the issues mentioned above are also relevant, such as the use of wait time, teacher nomination, support for students' language development and sensitivity to the possible language difficulties.

Regarding encouraging student questions, findings of this study revealed the language difficulties EMI students may experience in phrasing their questions clearly and the need for teachers to patiently wait until they complete uttering their questions. As this study shows, student-centred activities, such as class debates, may be a favourable environment that encourages higher-order questions from students.

The unique EMI scenario with monolingual teachers in this study also revealed students' strong need of L1 in EMI classes. While the importance of sufficient L2 exposure and negotiation of meaning in L2 is acknowledged, students' need of L1 to make connections with their prior knowledge and everyday experience, and knowing L1 equivalents to enable accurate and efficient comprehension of science ideas should also be considered. These factors are also

particularly important when there is a high quantity of unknown vocabulary to students and classroom interaction is very limited through L2 only.

It is also suggested in this study that EMI teachers' past ESL/EFL training and teaching background and high English proficiency alone are not sufficient to prepare them for EMI teaching. Classroom interaction strategies and a development of beliefs, as mentioned above, are important aspects that need to be catered for in EMI training.

This study also shows that students' beliefs could be different from their teachers' on key pedagogical issues. EMI teachers may also need to explore their students' beliefs about what they perceive is effective teaching of subject knowledge and English. To bridge the gap between the teachers' beliefs and students' beliefs, open and explicit discussion about certain issues may be helpful, so that the students are more inclined to corporate.

7.8.2 Implications for future research

Experimental studies are needed to examine whether a constructivist teaching approach with ample classroom interaction does lead to better learning outcomes in terms of content learning and language learning than a transmissionary one where the teacher does most of the talking. This would be particularly useful in the context where students have come from a more passive learning style without much participation in classroom talk.

This study has examined the interactional practices of a small number of monolingual teachers. within the context of the foreign high school programs in China. This EMI context bears several distinctive features, e.g., students' motivation of going overseas for university education, the use of curricula designed for L1 students. More studies on monolingual EMI teachers in other contexts are needed to enable more understandings about monolingual EMI teachers, who could

be a rising population with the growingly popular EMI education worldwide and an increasing demand for EMI teachers.

As explained earlier, teachers' and students' understandings of what language of science and general English mean and consist of were unclear in this study. Future research to clarify these issues would be helpful so that improvements can be made. More investigation is also needed to explore the role the general use of English, including the knowledge of grammar, plays in effective communication with teachers in EMI science classes, which emerged as an important issue in this study but is not yet thoroughly explored in the literature.

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Appendix 1 Teacher background questionnaire

EMI research Centre, Department of Education, University of Oxford
Contact information: Jiangshan.an@education.ox.ac.uk

We would like to ask you to help us by answering the following questions concerning the professional background of native English speaking teachers teaching foreign high school curricula in China. This survey is conducted by the English as the medium of instruction Research Centre at the University of Oxford. This is not a test so there are no right or wrong answers and you don't write your name on it. Please give your answers sincerely, as only this will guarantee the success of the investigation. Your answers to this survey are absolutely confidential. Information identifying the respondent will not be disclosed under any circumstances. Thank you very much for your help!

1.Basic information:

Nationality: _____ Age: _____ Gender: _____

Your email address: _____

2. Teaching experience Please list all your teaching experience, including in your home country, in China and other countries. Examples of curricula you have taught are the American / British/ Canadian high school curriculum, IB etc. Please start with your current job.

Name of the country	The curriculum you have taught	Grade level	Subject(s) you have taught	Number of years	Students' first language	language of instruction
(Your current job) China						

3. Qualifications

1).Please list the name of your academic qualifications and your teacher trainings (e.g. Bachelor of Arts, Master's in Science, teacher training programs etc.), which subject your degree/training is in, how long the program was, and which country your qualifications are from.

Academic qualifications and teacher training qualifications	subjects	duration	country

2).What training of Teaching English as a Second/Foreign Language do you have, if there is any? Please specify the name, the duration of the training, and where you obtained it from.

Name of the training program	Duration of the training	Country

3). What training of using English as the Medium of Instruction to teach non-English subjects (e.g. science, history etc.) to non-native English speaking students do you have, if there is any? Please specify the name, the duration of the training and where you obtained it from.

Name of the training program	Duration of the training	Country

4. Language background

1). What is your most proficient language? (It may or may not be the language you teach in.)

_____

2). What is the first language you learnt as a child?

_____

3). List all the foreign languages you have learnt and tick a box that can best show your proficiency of each. Please also indicate your level of Chinese.

Languages	low	medium	high
_Chinese_____	☐	☐	☐
Are you able to use Chinese to teach? (not using Chinese for administrative purposes)	Yes ☐	No ☐	
	☐	☐	☐
	☐	☐	☐

Thank you very much!

Appendix 2 Teacher beliefs questionnaire

EMI research Centre, Department of Education, University of Oxford
Contact information : Jiangshan.an@education.ox.ac.uk

We would like to ask you to help us by answering the following questions concerning teachers' beliefs about teaching science in English to secondary school students in China. This survey is conducted by the English as the Medium of Instruction Research Centre at the University of Oxford. This is not a test, so there are no right or wrong answers and you don't write your name on it. Please give your answers sincerely, as only this will guarantee the success of this research. Your answers to this survey are absolutely confidential. Information identifying the respondent will not be disclosed under any circumstances.

1.Science teaching in general:

The statements below describe different views concerning the ways science should be taught **in general**. Based on your **overall beliefs** about how science should be taught **in general**, indicate if you agree or disagree with each of the statements below, using the following scale:

SD: Strongly Disagree D: Disagree N: Neutral A: Agree SA: Strongly Agree

1.Interaction between teacher and students is important for learning science.	SD D N A SA
2. When introducing a new topic, asking students about what they already know about the topic is **NOT** necessary.	SD D N A SA
3. Teachers' monologue of explanation in most situations is more effective and helpful for students' learning than teacher-student interaction.	SD D N A SA
4. It is **NOT** useful for students to discuss and debate multiple possible answers with each other in class.	SD D N A SA
5. Students have difficulties learning scientific concepts mainly because their ideas about how the world works are often resistant to change.	SD D N A SA
6.When teaching a new topic, making reference to students' preconceptions is **NOT** necessary.	SD D N A SA
7. Students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.	SD D N A SA

8. In most classes, students' substantial verbal explanations of their ideas are **NOT** necessary. Having short verbal answers from students is good enough.	SD D N A SA
9. Experiments should be included in lessons as a way to reinforce the scientific concepts students have learned in class.	SD D N A SA
10. In most situations, teachers should do most of the talking in class.	SD D N A SA
11.Teachers should **NOT** let students' existing understandings, or their difficulties determine the direction and the focus of lessons.	SD D N A SA
12.Interaction among students is **NOT** important for learning science.	SD D N A SA
13.Teachers' elicitations of substantial verbal answers from students to explain their views are **NOT** necessary for students' learning.	SD D N A SA
14. Most of the questions in science classes should be about asking students to recall information.	SD D N A SA
15. Telling students' new knowledge upfront is more effective than helping students construct their own understanding based on their existing knowledge.	SD D N A SA
16. In general, questions that require students to compare and identify relationships between concepts are **NOT** necessary.	SD D N A SA

2. English language teaching in EMI* science classes

*EMI: the use of English language to teach academic subjects in countries or jurisdictions where the first language of the majority of the population is not English.

The statements below are specifically about EMI context, i.e., the students are not native English speakers. Indicate if you agree or disagree with the following statements in teaching EMI science classes. Use the following scale: SD: Strongly Disagree; D: Disagree; N: Neutral; A: Agree; SA: Strongly Agree.

In EMI science lessons:

1.I need to focus on science, **NOT** English language.	SD D N A SA
2.It is **NOT** my task to teach the academic language required for learning science in English (e.g., the English language used in writing a lab report, describing phenomenon etc.) in my science classes.	SD D N A SA
3.The language of science (i.e., the specific way of using language to talk about science) in English is **NOT** a problem for my students.	SD D N A SA
4.The general use of English language (not science-specific language) is a problem in my students in their learning of science through English.	SD D N A SA
5.English language learning objectives should **NOT** be included as part of the lesson objectives in my science classes.	SD D N A SA
6.I would correct students' **oral** English in my science classes to improve their English.	SD D N A SA
7.I would correct students' **written** English in my science lessons to improve their English.	SD D N A SA
8. Explaining difficult words in textbooks or text-based notes to my students is helpful.	SD D N A SA
9. Teaching my students English grammatical structures commonly used in science texts (e.g. passive voice) is **NOT** important.	SD D N A SA
10. Modelling ways of using English language to develop arguments in science to my students is important.	SD D N A SA
11. 1).Students' **spoken** English language output is unnecessary for improving their English. 11.2). Students' **written** English language output is unnecessary for improving their English.	SD D N A SA SD D N A SA
12. In EMI science lessons, students do **NOT** need regular opportunities to talk about science in English.	SD D N A SA
13.1).Having students do work in science that requires them to give long **spoken** answers in English is helpful for them to improve their English. 13.2). Having students do work in science that requires them to give long **written** answers in English is helpful for them to improve their English.	SD D N A SA SD D N A SA

14. EMI science teachers do **NOT** need to have knowledge about English grammar.	SD D N A SA
15. I should have knowledge about my students' difficulties in learning English grammar.	SD D N A SA
16. EMI science teachers do **NOT** need to have knowledge about the way English is pronounced.	SD D N A SA
17. I should have knowledge about my students' difficulties in pronouncing English.	SD D N A SA
18. My explicit knowledge about how English language works is good.	SD D N A SA
19. I need to have better proficiency of using the language of science (i.e., the specific way of using language to talk about science).	SD D N A SA
20. I do **NOT** need to know about my students' difficulties in learning the language of science.	SD D N A SA

21. Suppose you have the following four choices for your science classes, please circle the option you prefer and explain why.

a. A bilingual science teacher (usually a Chinese person) who is highly proficient in both English and Mandarin to teach mostly in English and occasionally in Mandarin to help.

b. A bilingual science teacher (usually a Chinese person) who is highly proficient in both English and Mandarin to teach half of the time in English and the other half in Mandarin.

c. A native English speaking teacher who doesn't speak any Mandarin.

d. A native English speaking teacher who doesn't speak Mandarin, and a bilingual teaching assistant (usually a Chinese person) who is highly proficient in both English and Mandarin to help individual students.

Reasons: _____

Thank you very much!

Appendix 3 Interviews with teachers (pre-lesson, post-lesson and a general interview)

Pre-lesson interview with teachers:

1. What is this class of students like regarding their academic ability and English proficiency? (This was only asked at the first pre-lesson interview.)

2. What do you plan to do in this lesson and why?

   Probing questions:
   a.How are you going to make students understand?
   b.How will you use classroom talk to achieve your teaching purposes?

Post-lesson interview with teachers:

1. Do you think the lesson is representative of the normal lessons with this class of students? If not, in what way?

2. How did the lesson go?
   Probing questions:
   a.Do you feel students understood the lesson? Why or why not?

3. How did your teaching support your teaching purposes?

   Probing questions:
   a.How did you use teacher-student interaction to support your teaching purposes?
   b.How did you ask questions to support your teaching purposes?

4. What were the challenges of teaching this topic in English? How did you tackle them?

5. Did you manage to teach according to your plan (the way you approach the topic, not just the teaching progress)? If not, what are the reasons?

6. How much of the lesson content do you think has already been taught in Chinese to the students? How did it influence your teaching and the way you interact with the students?

The general interview with teachers:

Part A: Overarching questions

1. What's your overall teaching experience in teaching science through English to Chinese students like?
2. What challenges do you face in teaching science in the EMI context?

Part B: Science teaching beliefs

1. In general, what is effective teaching of science when using students' first language?

   Probing question:

   a.What is the value of teacher-student interaction?

   b.What is the value of student-student interaction?

2. What is effective teaching of science using students' second language? And do you implement this in your classes? Why?

   Probing questions:

   a.What is the value of teacher-student interaction?

   b.What is the value of student-student interaction?

   c.Do you use interaction in this way in your classes? Why?

   d.How do you think questions should be used?

   e.Do you use questions in this way in your classes? Why?

f.What do you think is the role of practical activities in science learning?

g.Do you use practical activities in this way in your classes? Why?

Part C: English teaching beliefs

1. What do you think is the role of English in teaching at the international department?
2. If you think it is your role to help students with your English, what do you think are effective ways of improving students' English in your science classes?

   Probing questions:

   a.How do you make students understand you?

   b.Do you use interaction to help students learn English? Why?

   c.Do you invite more students to talk more?

3. Do you implement these ways in your classes? Why?

Part D: Understanding of the context

1. Do you think the grade level influences how you interact with students? Why?

Appendix 4 Student beliefs questionnaire-studying a foreign high school curriculum in China

EMI research Centre, Department of Education, University of Oxford
Contact information : Jiangshan.an@education.ox.ac.uk

We would like to ask you to help us by answering the following questions concerning your experience of studying foreign high school curricula through English in China. This survey is conducted by the English as the medium of instruction Research Centre at the University of Oxford. This is not a test, so there are no right or wrong answers and you don't write your name on it. Please give your answers sincerely, as only this will guarantee the success of the investigation. Your answers to this survey are absolutely confidential. Information identifying the respondent will not be disclosed under any circumstances.

Please make sure you answer all questions. Thank you.

1.Background information

1).Name of the foreign curriculum you are studying (e.g. the Canadian high school curriculum, the American high school curriculum, IB) _____

current grade level_____

2). Have you learnt any non-language subjects in English before you entered the high school international department? (e.g. using English to learn Chemistry, Social Studies etc.)

1.Yes. ☐ which subjects: _____ 2.No. ☐

3).a. Do you go to tutorials after school?

b.If yes, which subjects are they for?

c.What could you get from the tutors that you don't get from your foreign teachers in classes?

2.Your motivation for attending the foreign high school program

a).Why do you choose to study a foreign curriculum rather than the Chinese one? Please list the reasons according to how important they are for you (e.g. the first reason is the most important reason).

1)

2)

3)

3.Experience with the foreign science teachers and learning science through English

Please indicate your answers by choosing strongly disagree, disagree, neutral, agree, strongly agree.

1). I very often don't understand the teacher in science classes.	SD D N A SA
2). In science classes, sometimes I know the answers to teachers' questions, but I don't answer because I am afraid of speaking in English.	SD D N A SA
3).In science classes, sometimes I know the answers to teachers' questions, but I don't answer because I don't know how to phrase it in English.	SD D N A SA
4).I think learning science through English has not really helped my English.	SD D N A SA
5). I like English more than before I started learning science through English.	SD D N A SA

6) a. Do you think English has caused any trouble in your science learning? Yes ☐ No. ☐

If yes, Why?

_____

b. What strategies have you taken to solve this problem?

_____

7). Suppose you have the following four choices for your science classes, which one do you prefer? Why?

a. A bilingual science teacher (usually a Chinese person) who is highly proficient in both English and Mandarin to teach mostly in English and occasionally in Mandarin to help.

b. A bilingual science teacher (usually a Chinese person) who is highly proficient in both English and Mandarin to teach half of the time in English and the other half in Mandarin.

c. A native English speaking teacher who doesn't speak any Mandarin.

d. A native English speaking teacher who doesn't speak Mandarin, and a bilingual teaching assistant (usually a Chinese person) who is highly proficient in both English and Mandarin to help individual students.

Reasons:_____-

8). What do you like and dislike about having a native English speaking monolingual science teacher?

What you like (please give reasons)	What you dislike (please give reasons)

4.Your understanding of science learning

The statements below describe different views concerning the ways science should be taught **in general**. Based on your **overall beliefs** about how science should be taught **in general**, indicate if you agree or disagree with each of the statements below, using the following scale:

SD: Strongly Disagree D: Disagree N: Neutral A: Agree SA: Strongly Agree

1).Interaction between teacher and students is important for learning science.	SD D N A SA
2). When my science teachers are introducing a new topic, let them know about my existing knowledge about this topic is **NOT** necessary.	SD D N A SA
3). In most situations, teacher's monologue of explanation is more effective and helpful for my science learning than teacher-student interaction.	SD D N A SA
4). It is **NOT** useful for us to discuss and debate multiple possible answers with each other in class.	SD D N A SA
5). I have difficulties learning scientific concepts mainly because my ideas about how the world works are often resistant to change.	SD D N A SA
6).When teachers are introducing a new topic, making reference to my preconceptions is **NOT** necessary.	SD D N A SA
7). I should be able to explore and conduct my own experiments with hands-on materials before the teacher introduces any new scientific concepts to us.	SD D N A SA
8). In most classes, students' substantial verbal explanations of their ideas are **NOT** necessary. Having short verbal answers from students is good enough.	SD D N A SA
9.) Experiments should be included in lessons as a way to reinforce the scientific concepts I have learned in class.	SD D N A SA
10). In most situations, teachers should do most of the talking in class.	SD D N A SA
11). Teachers should **NOT** let students' existing understandings or their difficulties determine the direction and the focus of lessons.	SD D N A SA
12). Interaction between students and students is **NOT** important for learning science.	SD D N A SA
13).Teachers' elicitations of substantial answers from students to explain our views are **NOT** necessary for my learning.	SD D N A SA

14). Most of the questions in my science classes should be about asking us to recall information.	SD D N A SA
15). Teachers telling us new knowledge upfront is more beneficial to my learning than teacher guiding us to construct new knowledge based on our existing knowledge.	SD D N A SA
16). Teachers' questions that require us to compare and identify relationships between concepts are **NOT** important.	SD D N A SA

17). a. What do you think is the effective way of learning science in general (no matter through English or Chinese)?

b. Do you think interaction with teachers is important for learning science? Why?

18). a. What do you think is the effective way of learning science in English?

b. Do you think interaction with teachers is important for learning science in English? Why?

5. Your understanding of English learning in your EMI* science classes

*EMI: the use of English language to teach academic subjects in countries or jurisdictions where the first language of the majority of the population is not English.

The statements below are specifically about EMI context.

Indicate if you agree or disagree with the following statements in the situation where English is students' second language. Use the following scale: SD: Strongly Disagree D: Disagree A: Agree SA: Strongly Agree

1 I need to focus on science in my science classes, **NOT** English language.	SD D N A SA
2.It is **NOT** my task to learn the academic language required for learning science in English (e.g., the English language used in writing a chemistry lab report, describing phenomenon etc.) in my EMI science classes.	SD D N A SA
3.The language of science (i.e., the specific way of using language to talk about science) in English is **NOT** a problem for me.	SD D N A SA
4.The general use of English language (not science-specific language) is a problem for me in learning science through English.	SD D N A SA
5.English language learning goals should **NOT** be included as part of the lesson objectives in my EMI science lessons.	SD D N A SA
6.I hope my EMI science teachers would correct my **oral** English in the EMI science classes to improve my English.	SD D N A SA
7.I hope my EMI science teachers would correct my **written** English in EMI science lessons to improve my English.	SD D N A SA
8. It is helpful to have explanations of difficult words in textbooks or text-based notes from my science teachers.	SD D N A SA
9. It is **NOT** important for my science teachers to teach us the English grammatical structures commonly used in science texts (e.g. passive voice).	SD D N A SA
10. It is important for my science teachers to model ways of using English to develop arguments in science.	SD D N A SA
11.1).**Spoken** English language output is unnecessary for me to improve my English. 11.2).**Written** English language output is unnecessary for me to improve my English.	SD D N A SA SD D N A SA
12. In EMI science lessons, I do **NOT** need regular opportunities to talk about science in English	SD D N A SA

13. 1).Doing work in science that requires long **spoken** answers in English is helpful for me to improve my English. 2).Doing work in science that requires long **written** answers in English is helpful for me to improve my English.	SD D N A SA SD D N A SA
14. My EMI science teachers do **NOT** need to have knowledge about English grammar.	SD D N A SA
15. My EMI science teachers should have knowledge about my difficulties in learning English grammar.	SD D N A SA
16. My EMI science teachers do **NOT** need to know about the way English is pronounced.	SD D N A SA
17. My EMI science teachers should have knowledge about my difficulties in pronouncing English.	SD D N A SA
18. My EMI science teachers have good explicit knowledge about the way English language works.	SD D N A SA
19. My EMI science teachers need to have better proficiency of using the language of science. (i.e., the specific way of using language to talk about science).	SD D N A SA
20. My EMI science teachers do **NOT** need to know about my difficulties in learning the language of science.	SD D N A SA

21. If you think learning English is also one of your tasks in science classes, what do you think is the effective way of learning English in your science classes?

22.1).Do you participate a lot in teacher-student interactions in science classes?

2).What are the major challenges for you to participate, if there are any?

Thank you very much!

Appendix 5 Interview with students (post-lesson interview)

1. Is the lesson representative of the normal lessons you have had with that teacher? If not, in what way?
2. Can you write down two things you have learnt in this lesson, and two things that you are not clear about (if there are any) on this piece of paper, please?
3. What did the teacher do to make you successfully learn these two things? Why were you not clear about these two things?
4. How do you feel about your learning in this lesson? How much have you understood the lesson?
5. What are the challenges of learning this topic/lesson in English? How did the teacher help you?
6. How much of the lesson content have you learnt in Chinese before? How did it influence the way you interacted with the teacher?

Appendix 6 Lesson observation sheet

School: _____ Class: _____ Date: _____

Lesson objectives (based on pre-lesson interview):	
Overall structure of the class:	
The overall teacher student interactional pattern	
Students' participation and output	
Teachers' use of questions	
Teachers' consideration of and feedback to students' own ideas about science	
Teachers' focus of the language	
Teachers' use of labs	

Appendix 7 The source of the items in teacher beliefs questionnaire

Section 1 Science teaching in general

Question items in Section 1 Science teaching in general	Source of the item
1.Interaction between teacher and students is important for learning science.	My own question
2. When introducing a new topic, asking students about what they already know about the topic is **NOT** necessary.	My own question,
3. Teachers' monologue of explanation in most situations is more effective and helpful for students' learning than teacher-student interaction.	My own question
4. It is **NOT** useful for students to discuss and debate multiple possible answers with each other in class.	Adapted from (8) in Sampson et al. (2013) questionnaire *'students learn the most when they are able to test, discuss and debate many possible answers during activities that involve social interaction'*
5. Students have difficulties learning scientific concepts mainly because their ideas about how the world works are often resistant to change.	Almost the same wording, from (5) in Sampson et al. (2013) questionnaire '*Frequently, students have difficulty learning scientific concepts in school because their ideas about how the world works are often resistant to change*'
6.When teaching a new topic, making reference to students' preconceptions is **NOT** necessary.	My own question, similar to Question 2 above. Similar content was also covered in Sampson et al.'s (2013) questionnaire but asked in using different wordings.
7. Students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them.	Almost the same wording as Item (9) in Sampson et al.'s (2013) questionnaire '*During a lesson, students should explore and conduct their own experiments with hands-on materials before the teacher discusses any scientific concepts with them*'.

8. In most classes, students' substantial verbal explanations of their ideas are **NOT** necessary. Having short verbal answers from students is good enough.	My own question
9. Experiments should be included in lessons as a way to reinforce the scientific concepts students have learned in class.	Almost the same wording as Item (12) in Sampson et al's (2013) questionnaire *'Experiments should be included in lessons as a way to reinforce the scientific concepts students have already learned in class*'
10. In most situations, teachers should do most of the talking in class.	Adapted from Item (17) in Sampson et al. (2013) questionnaire, *'students should do most of the talking in science classrooms'*
11.Teachers should **NOT** let students' existing understandings, or their difficulties determine the direction and the focus of lessons.	Adapted from Item (20) in Sampson et al. (2013) questionnaire, *'teachers should allow students to help determine the direction and the focus of a lesson'*
12.Interaction among students is **NOT** important for learning science.	Adapted from Item (18) in Sampson et al. (2013) questionnaire, '*Students should work independently as much as possible, so they do not learn to reply on other students to do their work for them*'.
13.Teachers' elicitations of substantial verbal answers from students to explain their views are **NOT** necessary for students' learning.	My own question
14. Most of the questions in science classes should be about asking students to recall information.	My own question
15. Telling students' new knowledge upfront is more effective than helping students construct their own understanding based on their existing knowledge.	My own question
16. In general, questions that require students to compare and identify relationships between concepts are **NOT** necessary.	My own question

Section 2: the role of English language in EMI science classes

Question items in Section 2 English language in EMI science classes	Source of the item
1.I need to focus on science, **NOT** English language.	Adapted from Lo (2014) questionnaire, about EMI teachers' perception of their roles, Section 1 Item 1 - *'Teaching subject content and English language are equally important in my content subject lessons'*
2.It is **NOT** my task to teach the academic language required for learning science in English (e.g., the English language used in writing a lab report, describing phenomenon etc.) in my science classes.	Adapted from Lo (2014) questionnaire, about EMI teachers' perception of their roles. Section 1 Item 2 - *'one of my (as an EMI content teacher) role is to equip students with academic language required for learning content subjects through English'*
3.The language of science (i.e., the specific way of using language to talk about science) in English is **NOT** a problem for my students.	My own question
4.The general use of English language (not science-specific language) is a problem in my students in their learning of science through English.	My own question
5.English language learning objectives should **NOT** be included as part of the lesson objectives in my science classes.	Adapted from Lo (2014) questionnaire, Section 3 Item 1 - *'when planning my content subject lessons, I always include some language learning objectives.'*
6.I would correct students' **oral** English in my science classes to improve their English.	Adapted from Lo (2014) questionnaire, Section 1 Item 2 - *'I feel responsible for correcting students' English in my content subject lessons'.* A differentiation between oral output and written output was made in this study.
7.I would correct students' **written** English in my science lessons to improve their English.	
8. Explaining difficult words in textbooks or text-based notes to my students is helpful.	Adapted from Lo (2014) questionnaire, Section 3 Item 2 - '*I always explain difficult words in textbooks or notes to students'*

9. Teaching my students English grammatical structures commonly used in science texts (e.g. passive voice) is **NOT** important.	Adapted from Lo (2014) questionnaire, Section 3 Item 3 - *'I always teach students some English grammatical structures (e.g. passive voice) in my content subject lessons.*'
10. Modelling ways of using English language to develop arguments in science to my students is important.	My own question This item reflects what Dialogic Teaching advocates about the role of language in science teaching. It is also one of the principles in Dialogic Teaching (Alexander, 2004).
11. 1).Students' **spoken** English language output is unnecessary for improving their English. 11.2). Students' **written** English language output is unnecessary for improving their English.	My own question This question is added because of the important role of output in second language learning and also the findings from previous studies often show in immersion/EMI classes student output is lacking. The same was also observed in the pilot study of this project.
12. In EMI science lessons, students do **NOT** need regular opportunities to talk about science in English.	Adapted from Hoare (2003) questionnaire, under the section 'beliefs, 5. Opportunities for students to use language purposefully, *22. In IS (integrated science) lessons in EMI schools, students need regular opportunities to talk about science in English.*'
13.1).Having students do work in science that requires them to give long **spoken** answers in English is helpful for them to improve their English. 13.2). Having students do work in science that requires them to give long **written** answers in English is helpful for them to improve their English.	13 (1) and 13 (2) were adapted from Hoare (2003) questionnaire, under the section 'beliefs, 5. Opportunities for students to use language purposefully, *6).it is important for students to do work in IS (Integrated Science) that requires them to give long spoken and written answers in English.'*
14. EMI science teachers do **NOT** need to have knowledge about English grammar.	Adapted from Hoare (2003), under the section 'beliefs, 4.language-related attributes of a science teacher, 2. language

	knowledge'. *'it is important for IS (integrated science) teachers to have some knowledge about the English language (e.g. grammar, the pronunciation system etc.) in order to support students' learning of science through English.*'
15. I should have knowledge about my students' difficulties in learning English grammar.	My own question This item concerns the third component of TLA (teacher language awareness), i.e., teachers' understanding of their students' needs.
16. EMI science teachers do **NOT** need to have knowledge about the way English is pronounced.	Adapted from Hoare (2003), under the section 'beliefs, 4.language-related attributes of a science teacher, 2. language knowledge'. *'it is important for IS teachers to have some knowledge about the English language (e.g. grammar, the pronunciation system etc.) in order to support students' learning of science through English.*'
17. I should have knowledge about my students' difficulties in pronouncing English.	My own question TLA
18. My explicit knowledge about how English language works is good.	My own question TLA
19. I need to have better proficiency of using the language of science (i.e., the specific way of using language to talk about science).	My own question TLA in the context of EMI science classrooms
20. I do **NOT** need to know about my students' difficulties in learning the language of science.	My own question TLA in the context of EMI science classrooms

Appendix 8 CUREC 1A

University of Oxford

CENTRAL UNIVERSITY RESEARCH ETHICS COMMITTEE (CUREC)

CUREC /1A CHECKLIST FOR THE SOCIAL SCIENCES AND HUMANITIES

The University of Oxford places a high value on the knowledge, expertise, and integrity of its members and their ability to conduct research to high standards of scholarship and ethics. The research ethics clearance procedures have been established to ensure that the University is meeting its obligations as a responsible institution. They start from the presumption that all members of the University will take their responsibilities and obligations seriously and will ensure that their research on human subjects is conducted according to the established principles and good practice in their fields and in accordance, where appropriate, with legal requirements. Since the requirements of research ethics review will vary from field to field and from project to project, the University accepts that different guidelines and procedures will be appropriate. Please check the CUREC website to ensure that you have the correct checklist for your project.

ONLY TYPE-WRITTEN CHECKLISTS WILL BE ACCEPTED. PLEASE DO NOT SEND HANDWRITTEN CHECKLISTS.

ONLY EMAILED APPLICATIONS WILL BE ACCEPTED. PLEASE DO NOT SEND APPLICATIONS BY POST.

What this checklist will not assess

This checklist does not cover research governance, satisfactory methodology, or compliance with the requirements of publishers when administering their tests or questionnaires. As principal researcher, it is your responsibility to ensure that requirements in these areas are met.

CUREC does not review studies classed as *audit* (see glossary and Decision Flowchart for CUREC on our website).

The use of an *asterisked word underlined* in this checklist indicates a phrase defined in CUREC's glossary. The glossary and further information on the University's research ethics procedures are available from the CUREC website: http://www.admin.ox.ac.uk/curec/

What this checklist is designed for

This CUREC /1A checklist is designed largely for research that falls within the Divisions of Social Sciences and Humanities where ethical issues are relatively few and straightforward. Interviews, field work and oral history are also included in the CUREC process.

The full CUREC /2 application is only required where certain project characteristics (eg type of participants, or procedures) result in a more complex set of ethical issues. It is expected that only in a limited number of cases will it be necessary for researchers to complete a CUREC /2 application. The checklist below will direct you to a CUREC /2 application if needed.

Office use only: IDREC Ref. No. _____

Date of confirmation that checklist accepted on behalf of IDREC: // //

Please complete the sections that follow and follow prompts to stop completion and/or submit other documents. ***Please indicate your answer to all the Yes / No questions with a type-written 'X'.***		
Example:	**YES**	**NO**
1) By taking part in the research, will participants be at serious risk of criminal prosecution (e.g. by providing information on drug abuse or child abuse)?	***X***	

SECTION A: filter for CUREC2 application.

This section determines whether your study raises more complex issues which require the completion of a full application for ethical review, known as the CUREC /2 application.		
1) Are research participants classed as '*people whose ability to give free and informed consent is in question*'? (This may include those under 18 (though see FAQ C12), prisoners or vulnerable adults) *Note: sometimes participants aged 16-17 are regarded as 'competent youths' and may be able to consent for research themselves. Please consult the FAQ C12 on the CUREC website. However, if any of your participants are aged 16 or under, please answer 'yes' here and also answer question 4) below.*	**YES**	**NO** ***X***
2) By taking part in the research, will participants be at serious risk of criminal prosecution (e.g. by providing information on drug abuse or child abuse)?	**YES**	**NO** ***X***
3). Does the research involve the *deception* of participants?	**YES**	**NO** ***X***
If you answered NO to all of the questions above please go to SECTION B. If you have answered yes to any question above continue to question 4 below.		
4) Is your project covered by one of our approved research protocol(s)? (see CUREC website) If yes, please give protocol number(s): Protocol 15	**YES** ***X***	**NO**
If you answered Yes to ANY of questions 1-3, and answered No to question 4, please STOP COMPLETING THIS CHECKLIST and do not submit it for ethical review. ***Instead, please complete the CUREC/2 application form, available to download from the CUREC website. Then submit the CUREC/2 for ethical review.*** ***If you answered Yes to ANY of questions 1-3, and answered yes to question 4, please go on to SECTION B.***		

SECTION B: contact details and project description (NB must be typed not handwritten).

Contact details	
1) *Principal researcher* / supervisor (if student research):	Professor Ernesto Macaro, Dr. Jane McNicholl
2) Name of student (if student research):	Jiangshan An
3) Degree programme, eg DPhil, BA, MPhil, BSc, MSc (if student research):	DPhil
4) Department or institute name:	Department of Education
5) Address for correspondence (if different from 4):	
6) University email address and phone contact:	Jiangshan.an@education.ox.ac.uk 07542391255
7) Name and status of others taking part in the project. Eg 3rd year undergraduate; post-doctoral research assistant:	

Project description	
8) Title of research project:	Native English speaking teachers' interaction with Chinese students in English as the Medium of instruction (EMI) classes: an exploratory study of the foreign curricular in secondary schools in China
9) List of locations(s) where project will be conducted:	Beijing, Shanghai, Tianjin, Nanjing, Jinan, Weifang, Guangzhou, (all cities in China)
10) If your research involves overseas travel or fieldwork, by the time the research starts, will you have completed and returned a travel risk assessment form? (This may be necessary to ensure that the activity is covered by the University's travel insurance – see http://www.admin.ox.ac.uk/finance/insurance/travel/)	YES / ~~**NO / N/A**~~
11) Anticipated duration of project:	_35___ months
12) Anticipated start date:	20 / 4 /2015
13) Anticipated end date:	31 /1 /2018

14) Title and brief lay description of *research* (about 150 words), plus description (about 200 words) of the nature of participants.

When describing the research, please include your methodology, how you are applying professional guidelines, and the use to which results/data will be put. Please also declare any conflicts of interest here.

When describing participants, please include criteria for inclusion/exclusion, method of recruitment, and processes (as appropriate) for consent to participate. To support your description please attach documentation such as:

recruitment and advertisement material eg a poster or invitation letter
information for participants to read before they agree to take part eg participant information sheet(s)
a document to record informed consent eg written consent form(s) or oral consent script in case of an oral consent process
a guide to interview questions (this may be a list of questions to be asked, or a preliminary scope of questions) or sample of other instruments such as a sample questionnaire
debriefing document after participants have taken part (if relevant)

Detailed guidance is found on the CUREC website

Title and brief lay description of research (150 words)

Title: Native English speaking teachers in the international department in public high schools in China: professional background and teaching beliefs, interaction with students and perception by students.

Description of the research:

This study is situated in the context where foreign high school curricula (e.g., British/American/Canadian high school curricula or IB) are in great demand and offered in many public secondary schools in China. The aim is to understand who the foreign teachers teaching those curricula are, their teacher talk and interaction with students in classes and students' perceptions of them and the foreign curricula.

Firstly, questionnaires will be disseminated to foreign teachers through emails to gather their professional background information and teaching beliefs (see P1 of the supplementary documents). These teachers will be reached with the help of the British Council in China as the British Council may have contact with a large number of foreign native English speaking teachers in China. Secondly, some public high schools offering foreign curricula in major cities in China will take part in the study. Data collection will involve lesson observations, followed by interviews with teachers and students (see P2 of the supplementary documents). Interviews before classes with teachers will also be conducted and all interviews will be audio-recorded. Lessons will be video-recorded to get an in-depth understanding of the teachers' talk and use of interaction with students. I will also audio-record students engaged in whole class discussion, video the teacher, observe and take notes. The video camera will focus on the teacher and/or the board throughout and any incidental images of students will not be seen by anyone else or used for research without further explicit permission.

Description of participants and obtaining informed consent (200 words)

The participants include foreign science teachers and students in the foreign curricula of public secondary schools in some major cities in China (Grade 10-12; age 16-18). Those target schools will be identified through the internet and their school websites. They will be contacted by email with an information letter in both English and Chinese (see P.3-4 of the supplementary documents) explaining the purpose of my study and what the data collection process will be like. If they agree with having me come to the school, I will distribute the information letter and consent form for teachers (see P 5-7 of the spplementary documents) in person. These two documents are only in

English as the teachers in my study are all native English-speaking. An interview and classroom observation timetable will be negotiated with the teachers who agree to participate in my study before data collection.

Prior to data collection, the information letter for parents (P.8-9 of the supplementary document) and students (P.10-11 of the supplementary document) and consent letter for students and parents (P.12) in both English and Chinese will also be distributed to the students on site to seek their and their parents' approval for participating in the study. Because this research involves normal classroom practices and typically developing students, Protocol 15.1 enables me to use opt-out procedures for this study. Since the study focuses on the foreign science monolingual teachers' talk and how they interact with students, the video camera focuses on teachers' behaviours rather than the students. However, the information letter will tell them about the nature of study, the data collection processes and how the study will comply with ethical procedures. The contact details of the researcher and the researcher's supervisors are provided to all participants in case they have futher enquiries about the study or have a complaint. The parents and students are given three days to consider before making a decision. The researcher will be in the school for one day so the students can ask questions in person. Participants who refuse to give their assent will not take part in any stage of this study. The recorded data of those who withdraw from this study at the later stage will be deleted.

15) What are the ethical issues connected with your research and what steps have you taken to address them?

Please do not answer 'none'.

The committee wants to see evidence that you have identified potential ethical issues with respect to your research and have taken steps to address them. These issues could relate to your own safety as a researcher, participant burdens/risks, and data protection/confidentiality. For more guidance on ethical issues, please see http://www.admin.ox.ac.uk/curec/resources/.

One possible ethical issue may be the confidentiality of the identities of the schools, teachers and students who participate in this research. The steps I will take are not to give any revealing information in my study that can expose their identity. For example, on top of not mentioning the name of the schools, I will not specify the city where the school is located. I will give all schools, teachers and students codes and pseudo names in my data analysis.

16) Will you obtain informed consent according to CUREC guidelines and good practice in your discipline before participation?	**YES**	**NO**
	X	
If you have marked No, please give a brief explanation and justification for this decision here:		
17) Will your research involve discussing sensitive issues?	**YES**	**NO**

This could be information relating to race or ethnic origin, political opinions, religious beliefs, physical/mental health, trade union membership, sexual life or criminal activities.		
If you have marked Yes, please make sure that you have included some supporting information (as directed in question 14 of this section) showing the range of questions covering these issues.		***X***

18) Will you ensure that *personal data* collected directly from participants or via a *third party* is held and processed in accordance with the provisions of the Data Protection Act?	**YES**	**NO**
	X	

19) How will you ensure that any personal or sensitive data are captured, transferred and stored securely?

In particular if data are to be captured electronically, please consult with your local IT department and, with respect to University IT security policies, please comment on how you will capture such data in the first instance, how you will transfer them over networks or via portable media and how and where data will be stored. For more information please see the University's web pages on research data management:
http://researchdata.ox.ac.uk/university-of-oxford-policy-on-the-management-of-research-data-and-records/

During the project, all video/audio data and the electronic copy of the questionnaires for teachers will be stored in an encrypted external hard disk with password protected. The disk and the paper questionnaires for students will be put in a locked cabinet which is only accessible to the researcher. The researcher will ensure all data will be stored securely and destroyed at the end of the DPhil research project. Only anonymised data will be made available to research publication. Assurances will be given that images of teachers and teachers would not be shown in any publication, without gaining permission from the participants.

SECTION C: methods and procedures to be used.

In this section, please mark X against as many methods or procedures as apply to your research. (This section will help the committee understand the nature of your research and may be used for audit).

	Please mark 'X'
1) Analysis of existing records	
2) Snowball sampling (recruiting through contacts of existing participants)	
3) Use of casual or local workers eg interpreters	
4) Participant observation	
5) Covert observation	
6) Observation of specific organisational practices	
7) Participant completes questionnaire in hard copy	**X**
8) Participant completes online questionnaire or other online task	**X**
9) Using social media	
10) Participant performs paper and pencil task	
11) Participant performs verbal or aural task (eg for linguistic study)	
12) Focus group	

13) Interview	**X**
14) Audio recording of participant	**X**
15) Video recording of participant	**X**
16) Photography of participant	
Others (please specify): Systematic observation (lesson observation with no interruption or interaction with the students)	**X**

SECTION D: professional guidelines and training.

In this section, please mark X against at least one of the following professional guidelines. You should use the principles listed in your chosen guideline(s) in conducting your own research. Note this is not an exhaustive list.		
Research specialism/methodology	**Association and guidance document (active links below)**	**Please mark 'X'**
Anthropology	Association of Social Anthropologists of the UK and Commonwealth	
Criminology	British Society of Criminology: Code of Ethics for Researchers in the Field of Criminology	
Education	British Educational Research Association Ethical Guidelines for Educational Research	**X**
Geography	Association of American Geographers Statement on Professional Ethics	
Geography	Royal Geographical Society: Research Ethics and Code of Practice	
History	Oral History Society of the UK Ethical Guidelines	
Law (Socio-Legal)	Socio-Legal Studies Association: Statement of Principles of Ethical Research	
Management	Academy of Management's Professional Code of Ethics	
Political Science	American Political Science Association (APSA) Guide to Professional Ethics in Political Science	

Politics	Political Studies Association. Guidelines for Good Professional Conduct	
Psychology	British Psychological Society Code of Ethics and Conduct British Psychological Society: Conducting Research on the Internet: (Guidelines for internet-mediated research)	
Social Research	Social Research Association: Ethical Guidelines	
Sociology	The British Sociological Association: Statement of Ethical Practice	
Visual Research	ESRC National Centre for Research Methods Review Paper: Visual Ethics: Ethical Issues in Visual Research	
Other professional guidelines ***Please specify the other guideline(s) used here:*** Protocol SSD/IDREC/2013/P15.1		

Please indicate what training in research ethics the researchers involved with this study have received, e.g. the title of the course and date completed (online training available at http://www.admin.ox.ac.uk/curec/training/) If no formal training has been received, please indicate any discussions of research methodology between researchers and supervisors here.
The online training offered by the Faculty of Social Science 'Research Integrity: Social and Behavioural Sciences' A session in the Foundation of Educational Research module: 'Research Ethics' given by Dr Nigel Fancourt and Dr David Mills at the Department of Education on 19th of November, 2014.

SECTION E: Signatures.

Please ensure this checklist is signed by:

For staff research:	*For student research:*
1) *Principal researcher*	**1) *Principal researcher* (project supervisor)**
2) Head of Department (or nominee)	**2) Head of Department (or nominee)**
-	**3) Student researcher**

1) Principal researcher signature / supervisor signature (if student research)

I understand my responsibilities as *principal researcher* as outlined in the CUREC glossary and guidance on the CUREC website.

I declare that the answers above accurately describe the research as presently designed and that a new checklist will be submitted should the research design change in a way which would alter any of the above responses so as to require completion of CUREC/2 (involving full scrutiny by an IDREC). I will inform the relevant IDREC if I cease to be the principal researcher on this project and supply the name and contact details of my successor if appropriate.

Signed by principal researcher / supervisor:  …

Print name (block capitals) …Jane McNicholl……..

Date …13 March 2015…….

2) Departmental endorsement signature

I have read the research project application named above. On the basis of the information available to me, I:

(i) consider the principal researcher to be aware of her/his ethical responsibilities in regard to this research;

(ii) consider that any ethical issues raised have been satisfactorily resolved or are covered by relevant professional guidelines and/or CUREC approved protocols, and that it is appropriate for the research to proceed (noting the principal researcher's obligation to report should the design of the research change in a way which would alter any of the above responses so as to require completion of a CUREC/2 full application);

(iii) consider that the principal researcher/supervisor/student researcher is aware of her/his ethical responsibilities in regard to this research. I am satisfied that: the proposed project design and scientific methodology is sound; the project has been/will be subject to appropriate *peer review*; and is likely to contribute to existing knowledge and/or to the education and training of the researcher(s) and that it is in the *public interest*.

Signed by Head of Department or nominee: ……

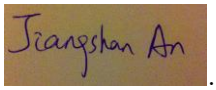
(example nominees for student research include the Director of Graduate Studies / Director of Undergraduate Studies)

Print name (block capitals) ……

Date: ……

3) Student signature (if student research)

I understand the questions and answers that have been entered above describing the research, and I will ensure that my practice in this research complies with these answers, subject to any modifications made by the principal researcher properly authorised by the CUREC system.

Signed by student: … ……..

Print name (block capitals) …JIANGSHAN AN……..

Date: ……9/3/2015……..

SECTION F: final check before submitting your application.

	Please mark 'X'
Have you completed Sections A-E?	**X**
Have you included copies of any documentation produced with your application? ***If the appropriate supporting documentation is not included with your application, you will then be asked to provide this separately. This may well delay the ethical review process, and thus the start of your research.***	**X**
Have you signed as principal researcher and gathered signatures of the student (for student research) and department nominees as appropriate?	**X**
Have you declared conflicts of interest (if any) in Section B question 14?	**X**
Are all pages (including supporting document attachments) numbered?	**X**
Have you defined all technical terms and abbreviations used?	**X**

How to submit the completed checklist

If your department has a Departmental Research Ethics Committee (DREC), submit this checklist and supporting information to the appropriate departmental officer. To see a list of DRECs, go to www.admin.ox.ac.uk/curec/about/sshidrec/drecs/

If your department does not have a DREC, submit the checklist and supporting information to the SSH IDREC (email ethics@socsci.ox.ac.uk***). NB applications must be sent by email. Please do not send applications by post.***
Note on how to send signatures needed in Section E

If you have obtained handwritten (wet-ink) signatures, please scan them plus the rest of the checklist pages to create a single PDF document and email through.

Alternatively, we accept 'electronic signatures' sent as email confirmations from a University of Oxford email address. Separate emails should come from each of the relevant signatories as outlined in Section E, indicating acceptance of the relevant responsibilities.
IDRECs and/or CUREC will review a sample of completed checklists and may ask for further details of any project.

Appendix 9 Information letters and consent forms

1.Information letter for Principles and teachers

UNIVERSITY OF OXFORD
DEPARTMENT OF EDUCATION

15 Norham Gardens, Oxford OX2 6PY
Tel: +44(0)1865 274024 Fax: +44(0)1865 274027
general.enquiries@education.ox.ac.uk www.education.ox.ac.uk

Director Professor Ernesto Macaro

Dear Principle and teachers,

My name is Jiangshan An, a doctoral student at the Department of Education at the University of Oxford. I am writing to invite you to participate in my doctoral research, supervised by Professor Ernesto Macaro and Dr. Jane McNichol. Before you decide whether to participate, it is important to understand why the research is being conducted and what your participation entails. Please take time to read the following information carefully. Please ask if there are any aspects of the project that are unclear or if you would like more information.

This study is situated in the context where foreign high school curricula (e.g., British /American /Canadian high school curricula/ IB etc.) are on great demand and offered in many secondary schools in China. The aim is to understand the professional background of the foreign science teachers of these curricula, their teaching beliefs, their interaction with Chinese students in classes, and students own learning experience.

To carry out this research, I would like to conduct an anonymous questionnaire to understand teachers' professional background and teaching beliefs, and also lesson observations to understand teachers' interaction with Chinese students. In addition, I would also like to have a short interview before and after classes to respectively obtain more understandings of the teachers' teaching beliefs and practice. The lessons will be video-recorded and the interviews will be audio-recorded with teachers' permission.

The research project has been approved by the Ethics Committee of the University of Oxford. This means the data collected is subject to the Data Protection Act, which protects the participants' identities and the school's identity. You are assured that all data collected (including the videos of the lessons, the audios of the interviews and questionnaires) will be used only for this research and will not be disclosed to anyone without your permission. All participants will be anonymized in the report. The school and the teachers can withdraw from the study at any time. During my visit, I will also not interrupt or intervene with the lessons in any way.

The findings of the research will provide valuable insights into the teaching and learning between foreign teachers and Chinese students in the foreign high school programs in China, which will help to understand the current teaching practice and promote effective teaching in the future in this particular context. The results of this research will form the basis of my doctoral dissertation at Oxford. I would be happy to offer you a copy of the written report upon completion of this research.

During my stay at your school, I would love to help in any way with the teaching and learning in your school. I could share my past learning and teaching experience in Hong Kong and Oxford, if that's useful for the students. I sincerely hope you would consider participating in this research. If you have any inquiries about the research, please feel free to contact me at Jiangshan.an@education.ox.ac.uk.

Yours sincerely,

Jiangshan An, Tiny
http://www.education.ox.ac.uk/about-us/directory/jiangshan-an/
Jiangshan.an@education.ox.ac.uk

2.Information letter for students

UNIVERSITY OF OXFORD
DEPARTMENT OF EDUCATION

15 Norham Gardens, Oxford OX2 6PY
Tel: +44(0)1865 274024 Fax: +44(0)1865 274027
general.enquiries@education.ox.ac.uk www.education.ox.ac.uk

Director Professor Ernesto Macaro

亲爱的同学们，

大家好！我是安江珊，牛津大学教育系的博士生。我这封信的目的是想邀请大家参与我的博士的研究课题。本课题是由 Macaro 教授和 McNichol 博士督导的。请大家仔细阅读以下的解释说明，如有不明白的欢迎大家询问。

近年来中国涌现了越来越多的由外籍老师用全英文教授的中学课程 （比如加拿大，美国，英国的高中课程， IB 等），本研究目的是探讨外籍理科老师的专业背景，教学的理念，如何用全英文与中国学生互动，中国学生的学习理念以及他们用全英学习理科的经历等。

本研究的设计包括看理科外教老师的课，以及录影以便之后做数据分析来了解理科老师的教学方式和与大家的互动。录影的焦点是老师以及黑板。这些录像会严格保密，只用于研究用途，未经大家的同意不会给除我之外的人观看。除观课之外，我也会在观课后与少数几位同学做课后的采访，目的是通过具体的例子来了解大家用英文学习理科的经历和困难。我将把采访过程录音。同样的，采访的录音也会严格保密，只用于本研究用途，未经你的同意，不会给除我之外的人听。最后一项是问卷，问卷是匿名的，主要询问大家对于用英文学习理科的观念和经历。

本研究已经经过牛津大学研究道德委员会批准，这意味着本研究所收集的数据会受数据保护法案的保护，也就是所有大家的个人信息会被严格保密。你可以不用担心本研究的数据(包括观课的录影，采访的录音以及问卷) 会被除我之外的人接触。在未经你的同意之前，这些数据不会向任何人展示。

所有参与本研究的同学，以及贵校，在我的博士报告中会被匿名，以代码的形式出现。请大家放心。你可以在任何时候退出本研究，不会有任何的处罚。在我观课的过程中会，我不会大打搅大家上课。所以，请大家照平日上课的模式就可以。

本研究希望可以中国学生用全英文学习理科的现状，经历以及困难，同学们和老师们的需求，希望能更好的促进教学。如果对于我的研究大家有不明白的地方，欢迎大家咨询。谢谢大家！如果同学们有什么学习或升学方面的问题，也欢迎大家来与我讨论，我很愿意给大家提供力所能及的帮助。如有不清楚的地方，也可以发信到我的邮箱 jiangshan.an@education.ox.ac.uk.

如果有同学不愿意参加本次调研，请填写下一页的“不参与表格”。谢谢。

安江珊

Jiangshan.an@education.ox.ac.uk

牛津大学教育系

15 Norham Gardens,

Department of Education,

University of Oxford,

UK, OX2 6PY

不参与表格

研究题目：全英课堂中的外籍教师与中国学生的互动

研究员： 安江珊

我已经阅读了研究介绍信，并且我有机会询问关于此研究的事宜。但是我不愿意参加本次调研。

学生姓名:

日期:

Appendix 10 Examples of non-content talk

Two examples of non-content related talk are as follows:

Chris second lesson:

Turn	Timespan	Content	Speaker	code
15	9:38.0 - 11:14.2	[T collecting the quiz from the class]	T	non-content related

Colin first lesson:

Turn	Timespan	Content	Speaker	code
8	3:47.4 - 4:44.8	At 11:00? Why don't we take that, why don't we take a little break now, right, and uh, then let's just say, we're supposed to be here at, at, uh, 11:10, okay? Why don't we just do that, be here at 11:10, but if you're out in the hallway, please, please don't make too much noise, 'cause then I'll get in trouble for letting you out a little early, okay? All right, or maybe if you're an astute student, you might take a chance and work on some of these, but I don't see that happening [laughter] in the near future. I know you guys too well. Um, what I will be doing afterwards is we'll be looking at-- I'll be handing back your Chapter 11 assignments, and I know I'm doing a lot of talking today, again, but I want to go through the assignments because you have that test tomorrow, okay, 10, Chapter 10-11, so I want to get it back to you, and talk to you generally about it.	T	non-content related

Appendix 11 Lesson transcription protocols

the transcription protocols

T: teacher

S1, S2, S3 etc: single students

Ss: more than one student

Student's name was transcribed if this was known

. . .[inaudible]: inaudible utterances

[gestures]: description of the speaker's pauses, behaviours and gestures

[pause for XX seconds]: description of how long the speaker paused

****…..*: overlapping utterances***

Words in bold: emphasis

<u>Words underlined</u>: slow down

'italics*': the words read aloud from worksheets, PPT or textbooks.*

(explanation): researcher's explanation of what the pronouns mean, e.g. are they (the PPT slides) useful?

Wait time: wait time that is longer than one second needs to be marked as a separate turn.

Appendix 12 Confidentiality form for transcribers

Confidentiality Form

I, _____ (name of the research assistant), am hired to transcribe lessons and interviews for Ms Jiangshan An's research project. I will be given video clips of the lessons and audio recordings of the interviews. By signing this agreement, I agree to not show or share the videos and audios, or any information about them to anyone, to protect the privacy of the participants of this research. I also agree I will delete the videos and audios immediately after the transcription is completed.

Name of the research assistant: _____

Signature:_____

Date: _____

Appendix 13 A sample transcript for training the transcribers

Transcription task training

Please keep this document to yourself and do not send it or show it to anyone. As the confidentiality agreement requests, all information related to the data (lessons or interviews) should be kept strictly confidential.

The requirement is transcribing verbatim (exactly word by word).

Please mark 'timespan', 'content' and 'speaker' as the columns. A sample of the transcription is provided below. Please read it carefully and follow the same format.

Turn [please mark the line number]	**Timespan**	**Content**	**Speaker**
1	4:13.0 - 4:21.9 [please follow this format: Minute: second. minisecond. If you can't figure out the minisecond, please just write 0, e.g. 1:14.0]	ok, ok so we talked about glucose or monosaccharide, right?	T [please write 'T' for teachers'
2	4:21.9 - 4:22.6	Er yes. [please transcribe all the exact words/sounds. If the grammar is wrong, please do not correct it. And if there are 'hugh, ah, em', please include all of them]	Ss [write 'Ss' if it's more than one student answering the question]

3	4:22.6 - 4:31.2	Em, Jessie, what is, could you give me an example of a disaccharide, disaccharide?	T
4	4:31.2 - 4:39.1	[wait time] (If there is any, please mark the time that teachers waited before the students started answering the questions for more than 2 seconds. If the wait time is shorter than 2 seconds, you do not need to mark it. VERY IMPORTANT!)	T
5	4:39.1 - 4:39.9	Two sugar.	Ss
6.	4:39.9-4:43.0	[wait time] [Please also mark the time that the teacher waited after the students finished their answer, if the wait period is more than 2 seconds. In this case, the teacher may wait to see if the students want to add more to their answer. If there is no wait time after students finished their response, you do not need to mark it.]	T
6	4:43.0 - 4:45.1	Two sugars? Could you give me a name?	T
7	4:45.1 - 4:50.9	er, er, [pause 3 seconds] Bitose. [Please mark all the pauses in teachers' and students' utterances if the pause is longer than 2 seconds]	Jessie [If the student's name was mentioned by the T, please write the student's name. Otherwise, if it's just one student answering the question, please write 'S1' /'S2']
8	4:46.9 - 4:47.3	Botose?	T

Other reminders:

T: teacher

S1, S2, S3 etc: single students. please mark 'S1', S2'…to show if it's the same several students answering the questions.

Ss: more than one student

. . .[inaudible]: inaudible utterances. E.g. You need to check textbook pages 1-2. *.....[inaudible]* Then we will conduct the experiment.

[gestures/pauses]: speakers' pauses, behaviours and gestures. E.g. The converging lenses *[T using gestures to show 'converge']* works this way.

***…..*:** to show overlapping utterances

E.g.

13:20.0-13:25.4	I meant to ask the meaning of epidermis. Is it the surface of	S1
13:25.4-13:27.0	*Yes*, the surface of leaves.	T

Words in bold: to show emphasis

Words underlined: underline the words to show the words are being slowed down

'*italics*': the words read aloud from worksheets, PPT or textbooks. Teachers and students may read aloud from textbooks/worksheets. Please mark these words in italics.

If there are recognizable sentences from the students in Chinese (e.g. using Chinese to talk to each other after the teacher asked a question), please also make sure to transcribe them as well. Please write the Chinese words the students said and then give the English translation of them in brackets afterwards. An example is as follows and if the students are talking to each other, please also mark that.

138	14:58.3 - 15:03.1	H two O, 那不是水吗？是啊(Isn't that water? Yes, it is.) [Ss talking to each other]	Ss

When the teacher was writing or drawing on the board, and referring it while he/she was talking, please take a screenshot of the board/teacher's gestures/PPT slide, and insert it in the transcript below the teachers' utterances in the 'content' column. This is because the teachers' use of visuals (drawings, use of an object, new slides) are also a very important part of the information the students are getting.

If the teacher is talking about administrative stuff (e.g. jokes, homework, taking attendance, discipline issues, arrangement of exams), you do NOT need to transcript that. What you need to do is to simply mark the time span and write 'T administrative talk', e.g.

If there are videos used in the lesson, you do NOT need to transcribe the videos. What you need to do is to simply mark the time span and write 'video' in the content column, e.g. *0:34.0-3:20.0 video.*

If students are doing practice/exercise themselves and teacher is not talking, please simply mark the start and end time and write 'Students self-practice' in the content column.

If students are doing group discussion, please also simply mark the start and end time and write 'group discussion' in the content column. You don't need to transcribe the content of the group discussion.

Often at the beginning of the 1st video clip there was some teacher talk which was not related to the lesson, or just some time period before the lesson started. You only need to transcribe from the place where the lesson has started, and the teaching of science content has started.

Please send the transcript in a WORD document to me.

Appendix 14 Examples of the coding of IRFs

1.Coding of T and S

IRF was adopted as a basic framework for quantitative analysis of classroom interaction in this study. The basic rule of coding using IRF was using the letter 'T' or 'S' before I, R, or F to indicate the speaker of this act. For example, 'T-I' stands for teacher-initiation, and 'S-R' stands for student response. An example from a lesson transcript is shown below.

Turn	Timespan	Content	Speaker	IRF
82	10:57.0- 10:59.0	Lipids are found in carbohydrates?	T	T-I (4)
83	10:59.1- 10:59.8	No.	S1	S-R (4)

The excerpt above, Turn 82 was coded as T-I (4). This means this utterance was from the teacher and it was an act of initiation. The number 4 means this cycle of IRF took place in the fourth cycle of an extended IRF sequence, which will be explained in the following section. Similarly, Turn 83 was marked as S-R (4), meaning this is a response from a student.

The use of the T and S marked the utterances from teachers and students, and this provided the basis for identifying teacher talk, student talk, teacher questions (coded as T-I), student questions (coded as S-I) in NVivo for the analysis of different aspects of interaction later on.

Again it needs to be noted that the time point in the timespan column in NVivo is presented in the format of XX:XX.X, as explained earlier. The first two digits before the colon are minutes and the two digits after the colon represent seconds. The last digit is mini second, counting from 0-9. Thus, '10:57.0' means 10 minutes 57 seconds and 0 mini second into the lesson.

2.Coding for the number of cycles in an extended IRF

A number was included as well in the codes of IRF, e.g., T-I (4) and S-R (4) in the excerpt above. This indicates the cycle of an extended IRF sequences an act was in. For example, T-I (1) means a teacher's initiation in the first IRF cycle. T-F (3) means teacher's feedback in the third IRF cycle of a coherent lengthy IRF sequence. The purpose of having the numbers was to examine the use of the extended IRF sequences in the lessons in a quantitative manner.

An extended IRF sequence includes more than one IRF cycle. When the initiations are follow-ups of the previous IRF cycle and are built up on the students' previous answers, these cycles of IRF form one extended sequence of IRF which follows one continuous line of thinking. For example, in the excerpt below, there were three IRF cycles, IRF-IR-IRF, and these three cycles formed one extended IRF sequence. The numbers also show which cycle each act was in.

Turn	Timespan	Content	Speaker	IRF
12	4:47.4 - 4:53.7	OK, err, Kathy, what is maltose made of? Maltose is made of what?	T	T-I (1)
13	4:57.1 - 4:57.6	Em, beer?	Kathy	S-R (1)
14	4:57.6 - 5:04.8	No, so maltose is in beer.	T	**T-F (1)**
15	5:02.0 - 5:04.8	But what are the chemicals that make up maltose?	T	T-I (2)
16	5:04.8 - 5:12.8	[wait time]		Wait time after T-I
17	5:12.5 - 5:23.4	Err, err, glucose.	Kathy	S-R (2)
18	5:13.6 - 5:15.4	Glucose and?	T	**T-I (3)**
19	5:15.3 - 5:23.0	And, err, err, glucose.	Kathy	S-R (3)
20	5:23.0- 5:25.2	Good! Glucose and glucose.	T	T-F (3)

As can be seen, the three IRF cycles in this one extended IRF sequence were all related to the first question *'what is maltose made of ?'.* In Turn 15, the T-I (2), '*But what are the chemicals that make up maltose?'* was a paraphrase or elaboration of the original question, and in Turn 18, the T-I (3), *'Glucose and ?'* was a repetition of the student's previous answer to elicit more answers to the original question. Thus, both the second and third IRF cycles were considered extension of the first IRF cycle. The T-I (2), '*But what are the chemicals that make up maltose?*' was a follow-up based on the student's response in Turn 13 '*Em, beer?'* in the previous cycle of IRF. This was a wrong answer to the original question in Turn 12 '*What is maltose made of ? Maltose is made of what ?*' and the teacher provided feedback by explaining '*No, so maltose is in beer'* in Turn 14. Then, he modified the original question and asked it in a different way in Turn 15 – *'But what are the chemicals that make up maltose?'.* This was considered still in the same IRF sequence as it did not start a different line of thinking.

In the previous literature, extended IRF sequences are often labelled 'IR-IRF' (Mortimer & Scott, 2003), where an F act in the first cycle, if there is any, was not specified. However, in this study any F act in an extended IRF sequence was coded, resulting in IRF-IRF chains rather than IR-IRF chains. Thus, the F in the previous cycle and I in the next cycle were coded separately as two acts. This was to reveal the exact function of each act. In some situations, there could be no F act in an IRF cycle. For example, in the second cycle of the excerpt above from Turn 15-Turn 17, there was only a teacher initiation (T-I) and student response (S-R) without a teacher feedback (T-F). The teacher directly moved on to a third initiation, coded as T-I (3) in Turn 18.

Another point to clarify is that the number indicates which cycle the move was in rather than the number of times this move had appeared. For example, the number 3 in T-F (3) in the excerpt above means this is the teacher's feedback in a third IRF cycle rather than it is the third time that teacher feedback appeared in this IRF sequence because there was no teacher feedback in the first two cycles.

3.The start of a new IRF sequence

A new IRF sequence was created when a question of a new topic was raised which was not built upon the previous cycles. An example is provided below.

Turn	timespan	content	Speaker	IRF
48	7:09.3 - 7:16.4	So, you can have a very severe disease but actually it's beneficial with other diseases. What is it?	T	T-I (1)
49	7:16.3 - 8:03.2	Err, it's called, err, what, [student looking for the answer from his notes]. Err, it's called, *sickle cell anaemia.*	S1	S-R (1)
50	8:03.2 - 8:05.3	Err hum, and what does it prevent?	T	T-I (1)
51	8:05.2 - 8:22.2	It prevents malaria. But, you know, it will have this sickle cell disease, but will prevent malaria.	S1	S-R (1)
52	8:17.7 - 8:21.3	So, one of the things you will have with a particular disease, like sickle cell anaemia, is you actually don't get other diseases like malaria. So, you can't contract malaria when you have sickle cell anaemia. So, it helps fight out other diseases.	T	T-F (1)

In the excerpt above, Line 48 and Line 50 were coded both as T-I (1), i.e., two separate single cycles rather than two cycles of one extended IRF sequence. This is because in Line 50, the question '*what does it prevent?'* is not a follow-up of the student's previous answer. The student's answer in Turn 49 was corrected and the next question from the teacher '*what does it prevent*' checked students' understanding of a different piece of knowledge, which is what kind of other diseases sickle cell anaemia prevents.

The decision of when a new IRF sequence starts may not always be a straightforward matter and the way it is conducted varies across different studies. In Nikula's (2007) work on comparing the IRF patterns in CLIL classes and EFL classes, the principle followed was that if an initiation addressed a new student, it was interpreted as the beginning of a new IRF sequence. Different from the rule of coding in Nikula's study, in this study, the start of a new IRF sequence did not depend on whether the question was directed to the same student or a different student. As explained earlier, a new IRF sequence starts when a question about a new issue or a new topic was asked. This rule of coding ensured only the extensive IRFRF sequences in the sense that the students are asked follow-up questions to further explain their ideas and develop their arguments were identified, which is argued to be beneficial for science learning (Mercer & Littleton, 2007;

Mortimer & Scott, 2003). This rule is important to establish because it influenced the analysis of the use of multiple-cycled extended IRF sequences later.

The comparison above shows that different studies may adopt different rules when using IRF as a coding framework. In summary, the principles adopted in this study aim to allow the identification of the speakers of each act, all the acts (including F acts in extended sequences), and the degree of the use of extended IRF sequences.

4.T-I (number) R: teachers' repetition and reformation of the same question

As emerged from the lesson data, one situation that frequently took place was that teachers repeated the same questions or reformulated the previous question with some degree of linguistic modifications. These questions were coded as 'T-I (number of the cycle) **R**', with R representing repetition or reformulation. Reformulated questions were the questions that were modified linguistically, for example, with semantics or syntax modifications, or simply restatements with only the key words of the questions. The science content of these questions was not changed.

The reason to mark these questions in the coding process was to differentiate them from the typical extended IRF sequences discussed in the literature where follow-up questions were asked to further the discussion. As explained in a number of studies (e.g., Alexander, 2004; Littleton & Mercer, 2013; Mercer & Littleton, 2007), the typical extended dialogues which are considered beneficial for science learning are based on follow-up questions built upon the previous one, which are different from the previous question, to elicit further answers and elaborations from students. The repetitions and reformulations in this study are not follow-up questions in this sense and thus it was deemed necessary to code them differently.

An example is shown below. Here the teacher had drawn the structure of several types of amino acids on the white board and he was pointing at these drawings to ask students to identify which part of these amino acids was the part that made them different.

Turn	Timespan	Content	Speaker	IRF
13	2:08.0 - 2:27.6	Ok, so what's the difference? There are 22 amino acid. What's the only thing that is different? Lucy, what's the only thing that is different about amino acid?	T	T-I (3)
14	2:27.6 - 2:31.4	Em....different?	Lucy	S-R (3)
15	2:31.4 - 2:32.8	What's the difference? So, so these parts [T pointing at the drawing]	T	**T-I (4) R**
16	2:32.8 - 2:35.6	[wait time]		WT after T-I
17	2:35.6 - 2:36.5	Ah, the nitrogen?	Lucy	S-R (4)
18	2:36.5 - 2:39.2	The nitrogen is different? [T pointing at N]	T	T-I (5)
19	2:39.2 - 2:41.5	Maybe?	Lucy	S-R (5)
20	2:41.4 - 2:42.8	What's the difference?	T	**T-I (6) R**
21	2:42.8 - 2:43.6	Different?	Lucy	S-R (6)
22	2:43.6 - 2:46.3	There are 22 amino acids, right?	T	T-I (7)
23	2:46.3 - 2:47.0	Yeah.	Ss	S-R (7)
24	2:47.0 - 2:54.7	What's different about, what makes these 22 amino acids different, if everything here is the same [T pointing to the drawing]?	T	**T-I (8) R**
25	2:54.7 - 2:59.2	Ohhh! The different order of... [S looking down at the textbook]. The R group.	Ss	S-R (8)
26	2:59.2 - 2:59.8	What?	T	T-I (9)
27	2:59.8 - 3:00.9	The R group.	S	S-R (9)
28	3:00.9 - 4:20.0	The R group, the R group on the side chain. So here it would be a R group, or this is a side chain [T drawing], meaning that, ok, so if there was, ok [T drawing, screenshot], there is an H, right? This is a Glycine. Or, it could be something like, [T drawing], so R group, the H could be a hydrogen, could be a, an acid, or other stuff, so it's always changing, a completely different R group for each amino acid. So, there are 22	T	T-F (9)

		different side chains.		

This extended IRF sequence consisted of nine cycles. It seems that the students had difficulties in comprehending the teachers' question '*what's the only thing that is different about amino acid?*', asked for the first time in Turn 13. This could be because students did not understand the meaning of the linguistic structure of this question (i.e. '*different about something*'), or they were not aware of the science idea that the differences among the 22 amino acids were due to one component in their structure. The teacher thus repeated and reformulated his questions several times, as shown in T-I (4) R, T-I (6) R, and T-I (8) R. For example, in Turn 15, the teacher modified the question into '*what's the difference? So so these parts [T pointing at the drawing]'* together with visual aids of the drawing of the structure of amino acids on the board.

5.T-I (number) A: teacher initiation for actions

Another rule of IRF coding is that when the teachers were giving directions of actions, e.g. look up your notes, these utterances were coded as teacher initiations for actions, T-I (A), with 'A' representing action. This was because they were meant to initiate certain actions from the students rather than eliciting verbal responses to form part of the classroom interaction. This type of teacher initiations was identified as different from the other teacher imitations and they were not counted in the analysis of the frequency and types of teacher questions later. Below is one example for teacher initiation for actions.

Turn	Timespan	Content	Speaker	IRF
43	13:33.0 - 13:38.0	Copy this down please. Copy this down	T	T-I (1) A
44	13:39.0 - 14:01.0	[Students taking notes from the PPT slide]		Ss notes taking

In the example above, the teacher's utterance in Turn 43 was coded as T-I (1) A, meaning this was an initiation from the teacher asking for actions from the students and it was the first IRF cycle. The action the teacher was trying to initiate from the students was copying what was being shown on the PPT slides. There was also no verbal response from the students, which was typical following a teacher's initiation for actions.

6. S-I: student initiations

As mentioned earlier, T or S was added in front of the act, I, R or F to indicate the speaker of this act. An example of student initiations is shown below.

Turn	Timespan	Content	Speaker	IRF
13	7:50.4 - 7:56.6	Ms Steele, this type of plant, they seem still have the primary root.	S1	**S-I (1)**
14	7:56.6 - 8:01.5	No, the primary root is only in the taproot system.	T	T-F (1)
15	8:01.4 - 8:04.4	Yes, so they don't have primary root?	S1	**S-I (2)**
16	8:04.3 - 8:18.0	Right, so the taproot system has two features [T pointing to the PPT as shown in screenshot 9], primary root and it has lateral roots.	T	T-F (2)

Although, the utterance in Turn 13 '*Ms Steele, this type of plant, they seem still have the primary root*' was not in the form of a question, it is understood that the student was essentially raising a question, and the teacher also realized this and responded with her explanation. The student's question was coded as S-I (1). The teachers' answers were coded as teacher feedback (T-F) because the teacher was giving an evaluation by saying '*No*' and an explanation '*the primary root is only in the taproot system*'.

In the example above, an act of evaluation was provided after the student's initiation. In other

situations, the teacher could reply to the student's question by a question or an answer directly without evaluation. They were coded as T-R (number) because they were a response to the student's question and did not have an evaluative function (e.g., No, that's incorrect. Yes, great question). An example is given below.

Turn	Timespan	Content	Speaker	IRF
5	1:27.9 - 1:39.2	Err, Ms Steele, the epidermis are all the covers of a leaf ...or just one type, err, just this certain type	S2	S-I (1)
6	1:39.2 - 1:41.2	What do you mean by covers?	T	**T-R (1)**
7	1:41.2 - 1:44.8	Err, the cover of.	S2	S-R (1)
8	1:44.7 - 1:50.3	*Oh! The epidermis covers the leaf surface [T pointing to the drawing, screenshot 17].	T	**T-R (2)**
9	1:50.3 - 1:52.0	Yeah, it could have many features.	S2	S-R (2)
	1:52.0 - 1:55.3	but they are all called epidermis?	S2	S-I (3)
10	1:55.3 - 2:08.3	Yes, so if you have a sticky leaf, that's still an epidermis that's causing, that's covering the leaf. If you have a hairy leaf, that's still an epidermis covering the leaf surface.	T	**T-F (3)**
11	2:08.3 - 2:14.9	So, it doesn't have a special name for different kinds of	S2	S-I (4)
12	2:14.9 - 2:27.8	Not that I know of. There might be on the textbook but now each leaf has a different name. Because depending on the plant, they have different shapes, and different sizes of leaves.	T	**T-F (4)**
13	2:27.8 - 2:28.7	Yeah, ok.	S2	S-R (5)
14	2:28.7 - 2:53.1	And the cuticle covers the epidermis.	T	**T-F (4)**

In this example above, Turn 6 *'What do you mean by covers?'* and Turn 8 *'*Oh! The epidermis covers the leaf surface'* were coded as teacher responses (T-R) rather than teacher feedback (T-F) or teacher initiation (T-I). This was because what the teacher said was not considered evaluative of the students' initiations, but rather providing a response to the student questions

through asking for clarifications or providing a direct answer. Thus, although the teacher's response in Line 6 was in the form of a question, it was decided in this research it should be treated as a response.

7.Coding of the debating lesson

As Nicolas's first lesson in Biology was largely occupied by a class debate activity, where the whole class was having a debate on whether stem cell research should be legal, the rule of IRF coding needs to be specially explained. In this lesson most of the talk was between two sides of the students, i.e. for and against stem cell research. It was decided that each time a student responded to the opposite side's argument a new cycle within the same lengthy IRF sequence was coded. This was because the responses students gave to each other was following up on each other's utterances and addressing the same topic. This was also to record the length of the exchange among students themselves before the teacher stepped in. An example is as follows:

Turn	Timespan	Content	Speaker	IRF
3	0:15.3 - 0:18.6	Do you wanna argue against that? Or do you wanna make a different point? [T talking to the girls]	T	T-I (1)
4	0:18.6 - 0:40.0	Listen, if you do the stem cell research, maybe you will have some medicine, err, if you don't do the research, maybe the person will die immediately.	S1	S-R (1)
5	0:40.0 - 0:56.0	But, what do you think about, did their feel, you just give them medicine maybe they will not recover and they, they just to need some other medicine to keep their life. They will be died more horribly and more uncomfortably. Do you think so? And maybe, ok you can say.	S2	S-R (2)
6	0:56.2 - 0:58.7	Err, it is the choice of this person and not decided by you.	S1	S-R (3)
7	0:58.7 - 1:28.0	No, but, err I think really immediately die, and, err, for the, you know, old people, old people do not want to die immediately, and they want to live longer, but you live longer, you will suffer more. And the suffer, the long suffer will cost, will, will, maybe I think, is, less than the, worse	S2	S-R (4)

		than maybe just dying immediately.		
8	1:25.6 - 1:58.2	OK, so that's a good point. So, yours were, you were saying it's a personal choice, I can choose whether I want to do that or not. You are saying just from a moral ethical standpoint, that it causes more pain, it can cause more suffering later on, and you don't necessarily know the choices. Maybe you were, just yeah I will take it, maybe you don't really know the consequences. So that's good.	T	T-F (4)

As the example above shows, S1 and S2 were arguing against each other without interaction with the teacher. The student responses in Turn 4, 5, 6, 7 were all given a new number to indicate they were from a different student adding up to the previous argument. Another feature of this special case of IRF coding was that there were no initiations in each cycle. This was because it was not a dialogue that was initiated by a question but was made of responses to each other's ideas. This way of coding only applied to this activity.

8.The possibility of not having all three acts in one IRF cycle

In some situations, an IRF cycle did not have all the three acts, i.e. all of I, R and F. The example below demonstrates this situation.

Turn	Timespan	Content	Speaker	IRF
110	12:16.7 - 12:21.3	You don't know? What type of liquid outside of a cell? Frank, do you know?	T	**T-I (1)**
111	12:21.3 - 12:23.2	[wait time]		Wait time after T-I
112	12:23.2 - 12:24.6	What type of liquid?	T	**T-I (2)**
113	12:24.6 - 12:25.1	Liquid?	Frank	S-R (2)
114	12:25.1 - 12:25.7	Yes.	T	T-F (2)

As it shows, the teacher asked one question in Turn 110, coded as T-I (1). As there was no response from students, the teacher asked again in Turn 112, coded as T-I (2), which formed a new IRF cycle. The teacher's question in Turn 112 was coded as the second cycle of a two-cycled IRF sequence built upon first one. The purpose of coding this dialogue as one continuous two-cycled IRF sequence rather than two single-cycled IRFs is to mark the effort teachers made to continue eliciting the students' answers. As can be seen in this example, after receiving silence from students in the first cycle, the teacher continued to pursue this line of questioning. The same principle of coding was applied to all the lessons.

Appendix 15 Examples of the constructivist teacher questioning approaches in Chin's (2007) framework

Following the justification of the selection of Chin's (2007) framework for analysing the constructivist use of questions by the teachers in the lessons of this study and detailed explanation of the question types, this section provides lesson excerpts to exemplify the question types.

During the coding process, not only the teacher questions were coded but also the student responses and teacher feedback that followed in the dialogue. The coding of all the turns in a dialogue reflects the holistic view of teacher questions in Chin's (2007) framework, as explained above. The coding of the whole dialogues also enabled NVivo to produce the time length of the whole dialogues where the questions were situated within. This measurement was used as one way of quantifying teacher questions, which is explained in Section 6.3 of Chapter 3 Methodology and shown in Section 2.11.2.3 in Chapter 4 Results of Classroom Interaction.

1.Pumping

The first example is from Christina's second lesson in Biology.

Turn	Timespan	Content	Speaker	T questions
11	2:03.0 - 2:17.0	So, um the strip in purple indicates normal magnetic polarity. What does that mean? Normal magnetic polarity?	T	pumping
12	2:17.0 - 2:20.0	[wait time]		pumping
13	2:20.0 - 2:21.0	Normal,	T	pumping
14	2:21.0 - 2:25.0	[wait time]		pumping
15	2:25.0 - 2:26.0	What do you think?	T	pumping
16	2:26.0 - 2:27.0	[Wait time]		pumping

17	2:27.0 - 2:39.0	So, if we are talking here the magnetic field of the earth, ok, and this here has hardened, it has recorded the what?	T	pumping
18	2:39.0 - 2:43.0	[wait time]		pumping
19	2:43.0 - 2:52.0	Now the urgh that the magnetic field of the earth [T using gestures to show “the strip”] the same as now, if it's normal?	T	pumping
20	2:52.0 - 2:54.0	[wait time]		pumping
21	2:54.0 - 3:24.0	Hum it's not really difficult. Anyways, so with this [audible] saying [T pointing at the ridge on PPT], when the rock had hardened, um, it recorded the earth magnetic field at its normal state.	T	pumping

The following example is from Lennon’s first lesson:

Turn	Timespan	Content	Speaker	T questions
23	4:07.8 - 4:10.7	All right, what equation do we use for this one?	T	pumping
24	4:10.7 - 4:14.1	I equal Q.	Ss	pumping
25	4:14.1 - 4:17.0	*OK [T writing I = Q/t on the board]. So try to find the current [T writing "I=],…	T	

In the examples above, the teachers used *pumping* to elicit students’ speculations and ideas rather than telling the students the answers themselves. In other situations, *pumping* could be embedded within the course of other questioning approaches, which are demonstrated under ‘*association of key words and phrases*’ and ‘*framing & zooming*’ below.

2.Association of key words and phrases

This excerpt below comes from George's first lesson in Biology:

Turn	Timespan	Content	Speaker	T questions
105	11:41.8 - 12:07.2	So, this was the cell [T drawing on the board], the cell memory. OK, outside of the cell, what type of liquid is outside of the cell? [pause 2 secs].	T	association of key words
106	12:07.2 - 12:09.3	[wait time]	T	association of key words
107	12:09.3 - 12:12.8	What type of liquid is outside of the cell?	T	association of key words
108	12:10.2 - 12:12.8	[wait time]	T	association of key words
109	12:12.8 - 12:13.6	Jessie, do you know what type?	T	association of key words
110	12:13.6 - 12:16.7	[wait time]	Jessie	association of key words
111	12:16.7 - 12:21.3	You don't know? What type of liquid outside of a cell? Frank, do you know?	T	association of key words
112	12:21.3 - 12:23.2	[wait time]	T	association of key words
113	12:23.2 - 12:24.6	What type of liquid?	T	association of key words
114	12:24.6 - 12:25.1	Liquid?	Frank	association of key words
115	12:25.1 - 12:25.7	Yes.	T	association of key words
116	12:25.7 - 12:26.5	[wait time]	T	association of key words
117	12:26.5 - 12:29.7	Is outside of the cell?	T	association of key words
118	12:29.7 - 12:31.4	Water?	Frank	association of key words
119	12:31.4 - 12:40.0	Yes, water! ok, so water is outside [T writing], ok this is outside, this is inside. water inside as well, right? So	T	association of key words

		water is outside and water is inside.		
120	12:40.0 - 12:59.8	But, in between here, in between the layer here [T pointing to the drawing, the cell wall], there is no water. What is the word for this layer?	T	association of key words
121	12:59.6 - 13:03.8	Lipid, fat	Ss	association of key words
122	13:03.8 - 13:04.7	What?	T	association of key words
123	13:04.7 - 13:04.8	Hydro,	S	association of key words
124	13:04.7 - 13:10.6	Hydro, hydro what?	T	association of key words
125	13:10.6 - 13:14.8	[wait time]	T	association of key words
126	13:14.8 - 13:16.0	Hydro something,	T	association of key words
127	13:16.0 - 13:16.2	Hydrophobic.	S	association of key words
128	13:16.2 - 13:39.7	Yes! hydrophobic, [T writing]. Ok, it's hydrophobic because these cells, are lipids. Hydrophobic.[T writing] It's hydrophobic because these tails (?) are lipids. Those are lipid tail(?), and a frosty head. frosty head (?).	T	association of key words

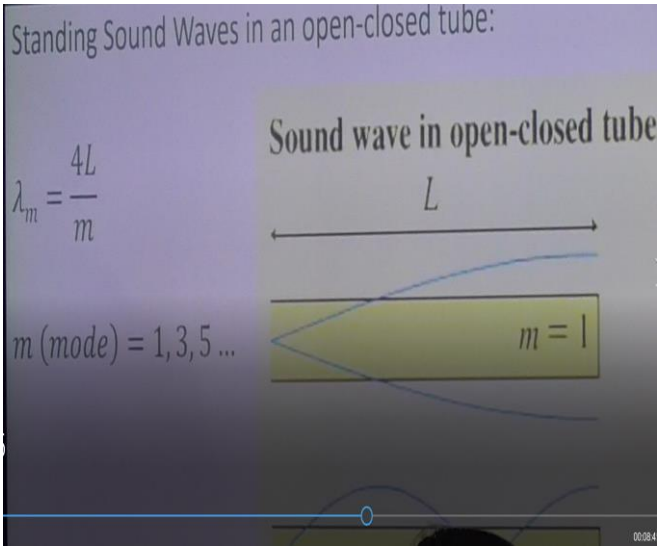
As can be seen above, the teacher was asking questions to require students to use certain science terminologies that they had learnt, such as lipid, hydrophobic to describe the science knowledge that the liquid outside and inside of cells is water and the liquid between the walls of a cell is lipid, which is hydrophobic.

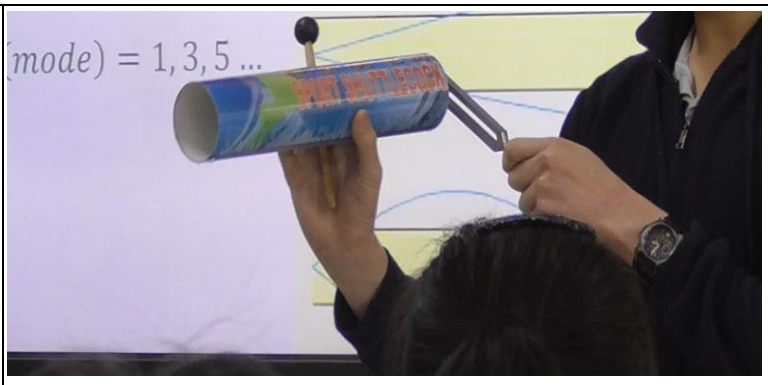
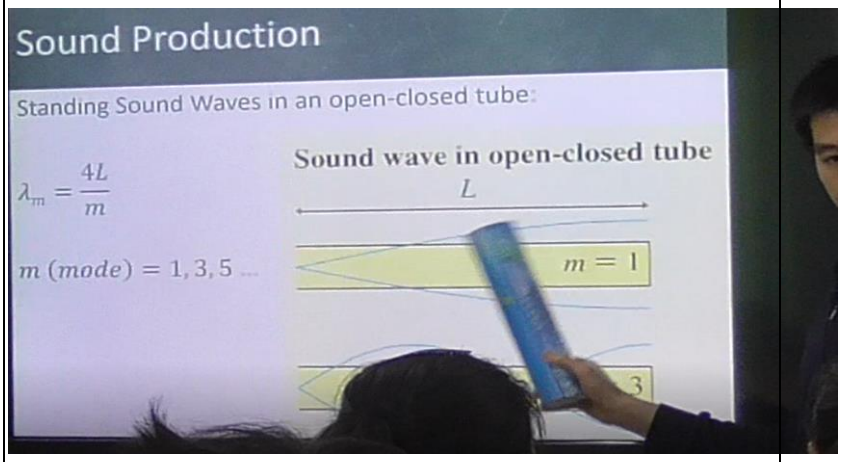
It needs to be noted that in Lines 124 – 126, the teacher asked '*Hydro, hydro what*' and this is also an example of the use of *pumping*. Thus, embedded within the overall use of *association of key words and phrases*, there was a brief moment of *pumping* as well. However, this sequence of dialogue was still classified as *association of key words* because the purpose of the questions all together was still considered primarily reinforcing and eliciting key science vocabulary (e.g.,

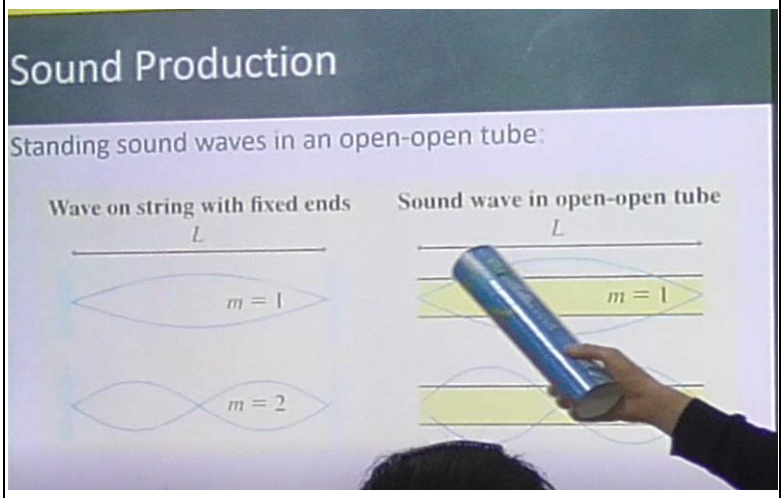
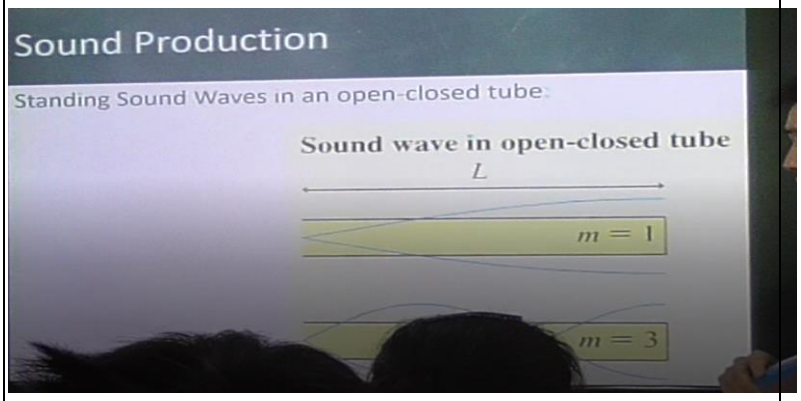
the type of liquid, hydrophobic) to help students form the declarative knowledge that the type of liquid inside of cells is water and the cell wall is lipid, which is hydrophobic. The phenomenon that *pumping* can be embedded into the use of other questioning approach is also demonstrated in '*framing and zooming*'.

3.Constructive challenge

The following example is from Johnson's first lesson in Physics. As can be seen, when students gave an incorrect answer in Turn 14, then the teacher asked a further question in Turn 15 and 17 to lead students to reflect on their answer. In Turn 18 the students came up with the correct answers themselves.

Turn	Timespan	Content	Speaker	T questions
11	13:11.0 - 14:17.0	So, you should be able to draw these pictures here to represent the sound wave.  Ok so I got these things here, seems broken, it doesn't work. If this one doesn't work, guess this one is gonna really work. [T hits the tuning fork] But maybe this is the wrong length. So, I wanted to uhm, make it work with this 512 Hertz one. This one works. [T tapped it and it worked]	T	constructive challenge

		 What do you think, do I need a longer tube or a shorter closed tube in order to make this work? [pause 2 secs] This is 512 Hertz, works with the open-open tube. Now it's a closed tube, but it doesn't work. Do I need a longer tube or a shorter tube than this [T holding a tube]?		
12	14:17.0 - 14:22.0	[wait time]		constructive challenge
13	14:22.0 - 14:24.0	What is your answer?	T	constructive challenge
14	14:24.0 - 14:25.0	Shorter maybe.	S2	constructive challenge
15	14:25.0 - 14:27.0	Maybe shorter, ok. Are you imagining the wave, the wave here? [T pointing to the diagram "m=1"] 	T	constructive challenge
16	14:27.0 - 14:28.0	Em! [S nodding]	Ss	constructive challenge
17	14:28.0 - 15:28.0	Yes you are imagining the wave here, OK, do you remember what the other one looks like? [T going back	T	constructive challenge

		with the PPT slides] So, the previous one, you can fit in half a wavelength. Half wave length for this L. [T pointing] Ok?  Here [T showing the next slide], we can fit in a quarter of the wavelength [T pointing at the diagram at the top "m=1"]  		
18	15:28.0 - 15:29.0	Er, longer!	S	constructive challenge
19	15:29.0 - 16:16.0	Ok you are changing your mind now? Does it need longer? Alright we will test it up here. …	T	constructive challenge

4.Multi-pronged questioning

The example below is taken from George's second Biology class. As Chin (2007) explained, *multi-pronged questioning* is employed when the teacher poses questions to address different aspects of a topic. In this example, the teacher addressed the topic of 'amino acid' through requiring students to produce verbal questioning and a drawing the structure of amino acids.

It needs to be noted that there are some differences in the use of *multi-pronged questioning* by the teachers in this research and the example given in Chin's (2007) article. As the example on p.829 of Chin's article shows, the teacher addressed the topic of classifying leaves with fictitious names through asking students to identify leaves based on textual description, and then based on drawings, and requiring students to describe a named leaf in words and drawing. Thus, the topic was explored through three different angles. However, it is generally rare in the 30 lessons in this research that a topic was approached through these many angles. Often, as shown in the example below, two different aspects or angles were included, such as processing verbal or textual information, and either requiring students to examine a given drawing or produce drawings themselves. Therefore, it could be said that 'bi-pronged questioning' was used most of the time than 'multi-pronged questioning'. This could be because of the difficulties the students might have with English and this restrained or slowed down the use of more angles in tackling a topic.

Turn	Timespan	Content	Speaker	T questions
117	13:01.6 - 13:19.1	OK, so on the next, so before I move to the next chapter, ok the monomer of nucleic acid is called nucleotide. We already talked about it right. Ok what is the monomer of proteins?	T	multi-pronged questioning
118	13:19.0 - 13:22.4	[wait time]		multi-pronged questioning
119	13:22.4 - 13:23.4	Proteins.	T	multi-pronged questioning
120	13:23.4 - 13:27.0	Amino acid.	S1	multi-pronged questioning
121	13:27.0 - 13:31.0	Yes, amino acid.	T	multi-pronged questioning
122	13:31.0 -	Do you know how to draw an amino acid? Yes, Lucy,	T	multi-pronged

	13:40.2	you?		questioning
123	13:40.2 - 13:42.4	Err.	Lucy	multi-pronged questioning
124	13:42.4 - 13:48.6	You know how to draw an amino acid? ok? So awesome! You come here and draw an amino acid. [T erasing board]	T	multi-pronged questioning
125	13:48.6 - 14:18.1	[S drawing on the board]		multi-pronged questioning
126	14:18.1 - 14:25.0	Ok, so this drawing is a very simple amino acid. This is an amino acid, called Glycine [T writing on the board].	T	multi-pronged questioning
127	14:25.0 - 14:36.6	How many amino acids are there? Lina, how many amino acids are there?	T	multi-pronged questioning
128	14:36.5 - 14:37.8	Five.	Lina	multi-pronged questioning
129	14:37.8 - 14:38.5	There are five amino acids.	T	multi-pronged questioning
130	14:38.5 - 14:40.7	Mercy, how many amino acids are there?	T	multi-pronged questioning
131	14:40.7 - 14:44.0	[wait time]		multi-pronged questioning
132	14:44.0 - 14:44.8	How many amino acids are there?	T	multi-pronged questioning
133	14:44.8 - 14:46.4	Two	Mercy	multi-pronged questioning
134	14:46.3 - 14:48.8	20.	S1	multi-pronged questioning
135	14:48.7 - 15:07.7	Yes 20, there are 20 different amino acids. 20. [T writing"20 amino acids"] ok, 20 amino acids right. ok so this is a very simple amino acid [T pointing to the S's drawing].	T	multi-pronged questioning

5.Stimulating multimodal thinking

The example below comes from Stella's first lesson. In this case, the teacher asked students to think between different modes about the concept of 'surface area of a root' through verbal and visual representations, i.e., the teacher showing her arm as a root and demonstrating the all of the surface of the arm would be the surface area if it were a root.

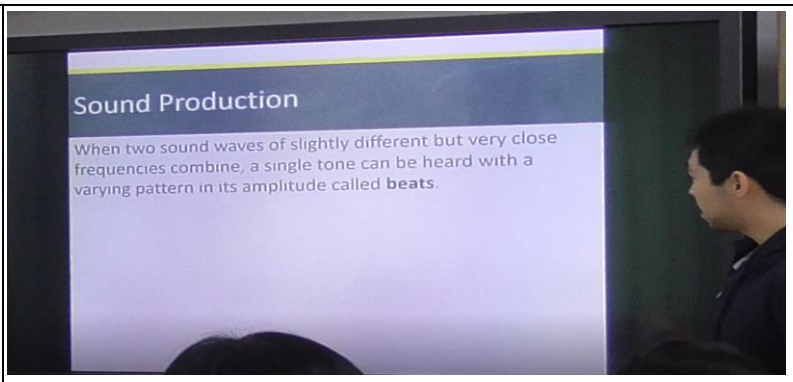
Turn	Timespan	Content	Speaker	T questions
58	9:59.1 - 10:25.0	So, roots are the plant structure that are often underground. Then we will go over their different functions over the next few slides. But the first thing you need to think about is roots have a large surface area. What is surface area?	T	stimulating multimodal thinking
59	10:24.9 - 10:30.0	[wait time]		stimulating multimodal thinking
60	10:30.0 - 10:30.7	Tommy?	T	stimulating multimodal thinking
61	10:30.7 - 10:36.5	Surface area is the area that, can, can be seen.	Tommy	stimulating multimodal thinking
62	10:36.5 - 10:48.6	Yes. One part of the definition is that we have a root, so let's say my arm is a root [T raising her arm]. Surface area will be the area that we can see.	T	stimulating multimodal thinking
63	10:48.6 - 10:51.6	But what part of the root is it? One side, all of it? [T pointing to her arm]	T	stimulating multimodal thinking
64	10:51.6 - 10:54.4	All.	Tommy	stimulating multimodal thinking
65	10:54.3 - 11:12.9	Good. So, you can think the root is a three D shape. Like my arm is root. Now the top, you can move my arm all around and look at all sides [T rolled her arm]. The surface area is going to be the total area of the root, like Tommy said, that we can see.	T	stimulating multimodal thinking

6.Framing & zooming

In this excerpt below from Johnson's second lesson about the wave of sound and interference, the teacher zoomed in and out with his questions to target students' thinking at the observational and auditory level and then at the conceptual and mathematical level. This was realized by, first of all, asking students questions about the actual sound of the beats through having students listen to beats produced by the teacher and the beats made by different sides of the class that overlapped, and then enquiring about the shape of the wave of the sound and the mathematical meaning of it.

Turn	Timespan	Content	Speaker	T questions
19	6:20.0 - 6:24.0	What am I doing here? I'm still making sounds. It's still music. But, what do you think that is? Actually, somebody tells me this one. [T banging the desk repetitively] What am I doing here? Is there a word for what I'm doing? [pause 5 seconds] Starts with a "B".	T	Framing & zooming
20	6:24.0 - 6:27.0	[wait time]		Framing & zooming
21	6:27.0 - 6:28.0	Bump.	S1	Framing & zooming
22	6:28.0 - 6:31.0	Sorry I didn't hear that. Did I hear "bump"? Do you have another word? Another "B"?	T	Framing & zooming
23	6:31.0 - 6:34.0	[wait time]		Framing & zooming
24	6:34.0 - 6:37.0	It's a music, you know you sort of count [T using gestures to show count]	T	Framing & zooming
25	6:37.0 - 6:38.0	Beat.	S2	Framing & zooming
26	6:38.0 - 6:43.0	Beats. Yeah. So, I'm making beats, right?	S2	Framing & zooming
27	6:43.0 - 8:19.0	So, when you're thinking about drum for making music beats, that's the one thing we'll be talking about today is, beats. How can we make beats? We can make beats by banging things. How about you guys make some beats too? Here what we're gonna try is, you take a look at, you see the	T	Framing & zooming

		clock, OK? A calculator for you. This side of the room, [T pointing to one side of the class] OK, you guys are gonna make a beat one every second. So, from this side, [T pointing to the middle] here, the middle line, to over here, every second I count it out, you guys make one beat. You guys over here at this side of the room, this side of the room, [T pointing to the other part of the class] you guys are gonna make a beat, two beats every second. OK? So, I will count it out. We're gonna make some beats together here. Alright, so ready, you count. Wait until it goes back to one here. [pause 4 seconds] OK. Ready. One, [Ss start banging the table] two, three, four, five, six, seven, eight, nine, ten, one, two, three, four, five, six, seven, eight. Two per second. Two per second. One, two, three, four, one, two, three, four. Alright, stop here. [Ss stop banging the table]		
28	8:19.0 - 8:22.0	Alright, you guys are making some beats, right?	T	Framing & zooming
29	8:22.0 - 8:23.0	Yes.	Ss	Framing & zooming
30	8:23.0 - 8:36.0	Now, they sound different. You know, when you, [T pointing to one part of the class] you were making beats yourself, and then combine [T pointing to the other part of the class] the beats over here. Does it sound any different than you were just doing it by, individually?	T	Framing & zooming
31	8:36.0 - 8:38.0	Yes.	Ss	Framing & zooming
32	8:38.0 - 8:50.0	And there was some overlap, right? [T pointing to one part of the class] You were doing one per second. [T pointing to the other part of the class] You were doing two per second over here. And there's a little bit overlap. So that's what happens when sound waves hit.	T	Framing & zooming
33	8:50.0 - 9:03.0	That's what we are gonna investigate today. So, interference. [pause 3 seconds] Alright, now, sound waves can create special things here. [T showing a new slide]	T	Framing & zooming

		 And we are gonna investigate beats. [T pointing to the slide]		
34	9:03.0 - 9:13.0	*[Ss taking notes]*	Ss	
35	9:14.0 - 9:18.0	Similar to … here. Similar to how the beats you created.	T	Framing & zooming
36	9:18.0 - 9:53.0	*[Ss taking notes]*	Ss	
37	9:53.0 - 10:12.0	Similar to what you just did. [pause 5 seconds] Sound and music mixed up, created something called beats as well. [pause 11 seconds] Now when we talk about, sound, when we talk about gravity, what kind of shape does sound have?	T	Framing & zooming
38	10:12.0 - 10:15.0	[wait time]		Framing & zooming
39	10:15.0 - 10:34.0	When we see it. [pause 9 seconds] When we draw sound waves, do we draw a straight line?	T	Framing & zooming
40	10:34.0 - 10:37.0	[wait time]		Framing & zooming
41	10:37.0 - 10:47.0	We represent sound with a straight line? Robin you've drawn, you know, right? What, what's that shape? What's the mathematical meaning for that? [T using gestures to show a wave] What's that shape of that we've been seeing for a wave here?	T	Framing & zooming
42	10:47.0 - 10:50.0	[wait time]		Framing & zooming
43	10:50.0 - 11:10.0	When we draw it out, something like this. [T using gestures to show a wave] What's the math meaning for that one? What function is that? It's a wave.	T	Framing & zooming

44	11:10.0 - 11:11.0	Curve.	S3	Framing & zooming
45	11:11.0 - 11:18.0	[wait time] [T pointing to S4]		Framing & zooming
46	11:18.0 - 11:20.0	Like sine curves, like sine or cosine?	S4	Framing & zooming
47	11:20.0 - 11:25.0	Yeah, sine or cosine, yes. So, it's a sine curve, yes.	T	Framing & zooming

It needs to be noted that over the course of *framing & zooming* in the example above, there was also an incident of *pumping* used in Turn 19-26, when the teacher asked '*what am I doing here? Is there a word for what I'm doing?*' and continued with '*Do you have another word?*'. It is considered that the teacher was trying to elicit information from the students rather than telling them directly. However, despite the use of *pumping*, the overall purpose of this whole questioning sequence is *framing & zooming*.

Again, as shown in the example here and the example of '*association of key words and phrases*' earlier, it is possible that the approach *pumping* could be embedded and interweaved into another approach. This could be because of the nature of pumping, which is broadly described as eliciting students to provide information and encourage student talk (Chin, 2007).

7.Question-based outlines

The following excerpt comes from Edward's first lesson in Biology. Here the teacher used questions to outline the process DNA transcription and translation by starting with requiring students to produce an outline of transcription and general question about the purpose of transcription, following with more specific question to lead students think through each step.

Turn	Timespan	Content	Speaker	T questions
106	13:30.0 -	Okay [pause 7 seconds] alright, more importantly let's talk	T	question-

	14:22.0	about, uh, transcription translation. [pause 4 seconds] Alright, transcription, what's going on during transcription? You could give me an outline of transcription. [pause 3 seconds] Unless you guys don't answer, and I'll come.		based outline
107	14:22.0 - 14:23.0	The ilocates like, urm, is it?	Natalie	question-based outline
108	14:23.0 - 14:24.0	Say again?	T	question-based outline
109	14:24.0 - 14:27.0	The ilocates…[inaudible]..the DNA	Natalie	question-based outline
110	14:27.0 - 14:43.0	Okay, the ilocates will bind to DNAs, which, uh, [inaudible] alright, it binds to all DNA or?	T	question-based outline
111	14:43.0 - 14:48.0	Like a specific, um, code	Natalie	question-based outline
112	14:48.0 - 14:52.0	A specific to the triplets, right?	T	question-based outline
113	14:52.0 - 15:00.0	Okay, um, what's the purpose of transcription?	T	question-based outline
(second clip of the lesson, the conversation continues from the above				
1	0:00.0 - 0:35.0	Codon, remember we start with the codon. And the anti-codon complements to that so if you wanna link the amino acid with what we read on the mra, the anti-codon provides that link, okay. [pause 4 seconds] okay, so what's the next step?	T	question-based outlines
2	0:35.0 - 0:36.0	elongation	S	question-based outlines
3	0:36.0 - 0:41.0	elongation, and what happens in elongation?	T	question-based outlines
4	0:41.0 - 0:48.0	the ribosome moves along, uh, another tRNA comes	S	question-based outlines

5	0:48.0 - 1:02.0	another tRNA comes [T is drawing on the board]	T	question-based outlines
6	1:02.0 - 1:07.0	and then what happens?	T	question-based outlines
7	1:07.0 - 1:20.0	an anti-codon…{inaudible] to	S	question-based outlines
8	1:20.0 - 1:30.0	Okay, good. Alright, and then what happens?	T	question-based outlines
9	1:30.0 - 1:37.0	the tRNA…[inaudible]	S	question-based outlines
10	1:37.0 - 2:30.0	uh, alright, but what has to happen before that? So, first, step one, initiation. [pause 3 seconds] Step 2, elongation, we're talking about the polypeptide chain is larger. Step 3, [pause 3 seconds] translocation right, [pause 4 seconds] that's when the, uh, the ribosome moves to the next, uh, the next, uh, codon. And then we also have the fourth step, what's the fourth step?	T	question-based outlines
11	2:30.0 - 2:31.0	Termination.	Ss	question-based outlines
12	2:31.0 - 2:39.0	Termination. When do we reach what? We reach	T	question-based outlines
13	2:39.0 - 2:40.0	Stop-codon.	Ss	question-based outlines
14	2:40.0 - 2:43.0	Stop-codon. What are the three stop-codons?	T	question-based outlines
15	2:43.0 - 2:44.0	UAG.	Ss	question-based outlines
16	2:44.0 - 2:46.0	UAG.	T	question-based outlines
17	2:46.0 -	UGA.	Ss	question-

	2:47.0			based outlines
18	2:47.0 - 2:48.0	UGA.	T	question-based outlines
19	2:48.0 - 2:49.0	UAA.	Ss	question-based outlines
20	2:49.0 - 3:41.0	UAA, good. Alright, I'm not asking you guys to memorize, uh, what codon goes with what amino acid. You get a chart for that, but you should know, should recognize the start-codon AUG and stop-codons, we have a trans-, a, um, sorry not a trans-, uh, a termination factor come out instead of a trna, sorry, releasing factor, um, and everything will break. Alright, now, when you guys look at the chart for the genetic code, it's going to read what? The codon, right? Not the anti-codon, it's going to read the codon.	T	question-based outlines

8.Absence of certain questioning approaches

Several approaches in Chin's (2007) framework were not present in the lesson sample of this study. Thus, it is not possible to use examples from the lessons of this study here. These questioning approaches include '*reflective toss*' under the category of '*Socratic questioning*', '*verbal cloze*' under '*Verbal jigsaw*', and '*question-based prelude*' and '*question-based summary*' under the '*Framing*'. However, examples can be found in Chin's (2007) article.

Appendix 16 Examples of non-constructivist teacher questions

1.Recall questions

In the first example below from Christina's first lesson, the *recall* questions took place within a revision activity in the beginning of the lesson, as the teacher explicitly explained in Turn 3.

Turn	Timespan	Content	Speaker	T questions
3	0:25.0 - 1:08.0	Alright. So, for first 5 to 10 minutes or so, again, like yesterday, what I would like you to do with a partner is to review and teach each other what is palaeomagnetism, sea floor spreading and hotspots. Hotspots. Ok? However, um, please do not look at your notes as much, but maybe what...but maybe you can look at the notes for a couple of minutes, ok? Once you are done and ready, you may put it away, and then you and your partner can start um...discussing. Ok? Go ahead.	T	
4	1:09.0 - 17:30.0	[group discussion, T explaining to Ss individually]		
5	17:31.0 - 17:34.0	Alright 10C, times up. Eyes up here.	T	
6	17:34.0 - 17:41.0	[T waiting for the students to be ready]		
7	17:42.0 - 17:50.0	Ok. Now, does everybody understand what is palaeomagnetism, and how it relates to sea floor spreading?	T	recall
8	17:51.0 - 18:00.0	[inaudible] continue uh give you the [inaudible]	Albert	
9	18:01.0 - 18:03.0	Why? Why it's happens?	T	recall
10	18:03.0 - 18:05.0	*it's what*	Albert	
11	18:04.0 - 18:05.0	You should [inaudible]	S1	
12	18:05.0 - 18:06.0	*[inaudible]*	Albert	

13	18:06.0 - 18:14.0	Wait one second----please---one person speaking at one time so I can understand you. So, Albert, can you please repeat your question?	T	recall
14	18:15.0 - 18:25.0	We don't know why palaeomagnetism have [inaudible] of the um [inaudible] edge	Albert	
15	18:26.0 - 18:40.0	Uh...So yeah, um...the [inaudible] palaeomagnetism ok? Um first of all, can someone tell me what is palaeomagnetism? What is palaeomagnetism?	T	recall

The coding of the *recall* questions, as can be seen above, unlike the coding of constructivist questions illustrated in the section earlier, only included the individual teacher questions but not the whole dialogue where the questions were situated within. This was because these non-constructivist questions were not developed based on how they led the students' productive thinking to move forward as discursive strategies but were rather used as individual act to check if students remember or understand certain information.

Another example of *recall* is shown below, from Edward's first Biology lesson. Here, the teacher questions were coded as *recall* because this lesson was a revision lesson to prepare students for an exam coming soon as the teacher explained explicitly in the beginning of the lesson.

Turn	Timespan	Content	Speaker	T questions
1	0:00.0 - 0:35.0	Codon, remember we start with the codon. And the anti-codon is complement to that so if you wanna link the amino acid with what we read on the mra, the anti-codon provides that link, okay. [pause 4 seconds] okay, so what's the next step?	T	recall
2	0:35.0 - 0:36.0	Elongation.	S1	
3	0:36.0 - 0:41.0	Elongation. And what happens in elongation?	T	recall
4	0:41.0 - 0:48.0	The ribosome moves along, uh, another trna comes	S1	

5	0:48.0 - 1:02.0	Another tRNA comes [pause 13 seconds – T is drawing on the board]	T	
6	1:02.0 - 1:07.0	And then what happens?	T	recall
7	1:07.0 - 1:20.0	An anti-codon…{inaudible] to	S2	
8	1:20.0 - 1:30.0	Okay, good. Alright, and then what happens?	T	recall
9	1:30.0 - 1:37.0	The tRNA…[inaudible]	S2	
10	1:37.0 - 2:30.0	Uh, alright, but what has to happen before that? So, first, step one, initiation. [pause 3 seconds] Step 2, elongation, we're talking about the polypeptide chain is larger. Step 3, [pause 3 seconds] translocation right, [pause 4 seconds] that's when the, uh, the ribosome moves to the next, uh, the next, uh, codon. And then we also have the fourth step, what's the fourth step?	T	recall
11	2:30.0 - 2:31.0	Termination.	Ss	

2.Vocabulary check questions

Below is an example from Christina's first lesson, which illustrates vocabulary check questions. As can be seen, they diverted the students' attention from science to language rather than working on vocabulary to help students form scientific mental framework. In addition, the vocabulary focused on in these incidents are also not strictly subject specific vocabulary but rather general science or general vocabulary. This incident below was also been coded as an 'language-focused episode (LFE)'.

Turn	Timespan	Content	Speaker	T questions
84	21:05.0 - 21:07.0	Now if you use a compass like this---do you know what this is? [T pointing at the compass on the slide]	T	Vocab check

				questions
85	21:07.0 - 21:08.0	Yeah.	S5	
86	21:11.0 - 21:12.0	Find directions.	S5	
87	21:12.0 - 21:14.0	Exactly! To find your way, to find direction. Ok?	T	
88	21:14.0 - 21:45.0	So basically, here [pointing at the compass in the slide], it's pointing North, it's the North um in the compass of lines with the South um magnetic field of the earth. So it's showing us that this way [pointing the upper part of the red bar] is north. Ok? However, about every 200 thousand years, or so, the magnetic field reversed.	T	
89	21:45.0 - 21:47.0	What does reverse mean?	T	Vocab check questions
90	21:47.0 - 21:48.0	*[inaudible]*	S6	
91	21:48.0 - 21:49.0	It---	T	Vocab check questions
92	21:49.0 - 21:51.0	*[inaudible]*	Ss	
93	21:52.0 - 22:01.0	Exactly, to change, to switch [T using gestures to show "change" and "switch"], ok? So, when there is a magnetic reversal, what happens is that the magnetic------	T	

3.Direct comprehension check questions

An example is given below, from Emma's first lesson in Chemistry.

Turn	Timespan	Content	Speaker	Questioning approach

32	16:38.0 - 16:42.0	Okay, so everyone understands all this?	T	Direct comprehension check questions
33	16:42.0 - 16:43.0	Yes	Ss	
34	16:43.0 - 16:45.0	Okay good.	T	

Appendix 17 Examples of student question types in Gallagher and Aschner's (1963) framework

1.Memory questions

The excerpt below is from Nicolas' first Biology lesson, providing an example of *memory questions.*

Turn	Timespan	Content	Speaker	Ss Questions
57	7:04.9 - 7:05.9	Law of dominance, OK? The reason I am saying this is because they are not up there, so you should have one, and you should have a, b, c, underneath it. So, there is the law of dominance.	T	
58	7:14.3 - 7:16.6	Louis, do you have another one?	T	
59	7:16.6 - 7:17.8	Err, err, part, part one was what?	Louis	memory
60	7:17.8 - 7:21.0	Mendel's laws, there are three laws that Mendel has, [T pointing to "Mendel's law" on the PPT]	T	
61	7:21.0 - 7:23.3	But the first one, is, is what?	Louis	memory
62	7:23.2 - 7:25.8	Dominance.	Ss	

Here in Turn 59 and 61, the student was asking about the content of the first Mendel's law among three of them, which was already taught in previous lessons. The student was asking for information through recalling.

2.Convergent thinking questions

The excerpt below is an example of *convergent thinking questions* that comes from George's first Biology lesson. The focus of the following excerpt is reviewing different types of sugar e.g., glutose, fructose, maltose etc.

Turn	Timespan	Content	Speaker	Ss Questions
54	8:41.5 - 8:43.7	What is the difference?	S	convergent
55	8:43.7 - 8:44.1	What, between them? [T pointing at monosaccharide and disaccharide on the blackboard]	T	
56	8:44.1 - 8:44.8	Yes.	S	
57	8:44.8 - 8:48.2	One has one, one has two.	T	

In this example, the student enquired about the differences between two concepts, monosaccharide and disaccharide. The cognitive operation this question requires is comparing and contrasting, and the correct answer of this question is fixed and not open. This means the question falls into the category of *convergent thinking*, which is one level higher than *memory question*, normally only asking for recalling and naming single facts rather than multiple facts.

3.Divergent thinking question

The excerpt below demonstrates a *divergent thinking question* from a student in Nicolas's first Biology lesson. It took place during a whole-class debate between boys and girls on whether stem cell research should be allowed and whether it is ethical.

Turn	Timespan	Content	Speaker	Ss Questions
50	11:32.2 - 11:52.0	I er I have a question. If we choose to do the research, and we finally, we get a disease maybe in the future, err, but, can we, if we found it, can do cure it by the [pause	S	divergent

		2 secs]		
51	11:51.9 - 11:53.9	If you do this research, can you cure it once you find it?	T	
52	11:53.8 - 11:54.9	Yeah.	S	
53	11:54.9 - 12:36.2	That's what they don't know. Because they haven't done enough research with it, because it's banned to be able to, for tell, hey, if we did this, we are now able to cure X, Y and Z, whatever the disease it is. So, because they are not even allowed to do it, this is still part of the debate. Because you have Richard's point of don't even start it because it's Pandora's box. You are opening something you don't know - what consequences can come out of it? And you are saying [T looking at the girls], just let us do it, and we can choose whether we want to use it or not. But by being limited to the fact that you can't even mess with it, still you still have the debate of what if, what's going on, I don't know.	T	

In this case, the student in Turn 50 was asking whether we can successfully cure diseases if stem cell research is allowed, in the middle of the debate. This is a question that does not have one single correct answer and requires predicting and hypothesizing to generate new ideas, based on the existing knowledge about stem cells. These cognitive processes are the typical ones involved in *divergent thinking questions*.

It needs to be pointed out that in this excerpt the student question, in Turn 50, was directed to the opposition team rather than the teacher, although the teacher also took part in this conversation by paraphrasing the student's question, as shown in Line 51. Thus, this is a different situation from the one where student questions were clearly targeted at the teacher.

4. Evaluative thinking questions

The following excerpt comes from Nicolas's first Biology lesson as an example of *evaluative thinking questions*. Similar to the example above, this excerpt also took place during the same debate on whether stem cell research should be allowed.

Turn	Timespan	Content	Speaker	Ss Questions
38	8:00.6 - 8:02.4	*So, you are prolonging the human species, but you are potentially threatening all the other species,	T	
39	8:08.2 - 8:19.3	Yeah, do you like this consequences? Just, you know, remaining all human beings will kill all other things out, err, err, die out.	S	evaluative
40	8:19.2 - 8:24.3	Right, which in turn kills us.	T	
41	8:24.3 - 9:08.4	Err, if it does not go out, the human's life. Because if you, if you die, you will, err, for example, err, one get cancel and he or she dead when he or she is 30 or 40, and we use stem cell research to help he, him or her to kill this disease, and so, err, they can, err, get live to maybe 60 or 70. It is not prolong his or her life because healthy person can live to this age. It's not anything prolong to him or her.	S	

In this example, the student in Turn 39 asked if the opposition team would like the consequences of keeping the human race but endangering other species. This question demonstrates the cognitive process of making value judgements regarding the correctness, which is an example of *evaluative thinking questions*.

Appendix 18 Examples of the two new types of student questions

1.Language-related question

The following excerpt from Stella's first lesson demonstrates a language-related student question. Here the student directly asked for help of specific language items.

Turn	Timespan	Content	Speaker	Ss Questions
8	3:00.2 - 3:03.6	What is, emm, anchor? What's that?	S	Language-related

Another situation where student questions were also coded as *language-related questions* were when the students indicated indirectly rather than directly the difficulty with certain language items. An example is given below, taken from Mat's first lesson.

Turn	Timespan	Content	Speaker	Ss Questions
3	0:38.0 - 0:43.0	Emm, it's quite interesting because what they do is determining how each gene in a mouse works by knocking them out.	T	
4	0:43.0 - 0:44.0	Em?	S	language-related
5	0:44.0 - 1:37.0	So basically, what they are doing is they taking the, the mouse code [T using gestures]. They are targeting a single gene and they are basically through, err, by using virus or plasmids, they are basically shoving in a sequence of DNA that's just junk DNA and doesn't mean anything, inside the gene. [pause 2 secs] And as you can imagine it destroys the gene, destroys the protein. Therefore, the protein doesn't work, so what you're doing is knocking that gene out. So for example, if you knock out one of the genes for hair colour, oh hair colour, for hair, you end up with naked mice, mice with no fur. [Ss laughters] [pause 3 secs] So, I, I , I actually err, stopped at the point where it was talking about ISIS and no one wants to watch	T	

		that. So, hopefully this work.		

Here in Turn 4, the student said '*Em?*', indicating possible communication breakdown. However, the student did not specify which part of the teacher's utterance in Turn 3 caused the problem. It could be because of the colloquial phrase '*knock out*', or the general academic word '*determine*'. Thus, it is unclear which word or phrases was difficult for the student, or the whole utterance. In this case, it was speculated that this question was caused by language problems and coded as language-related.

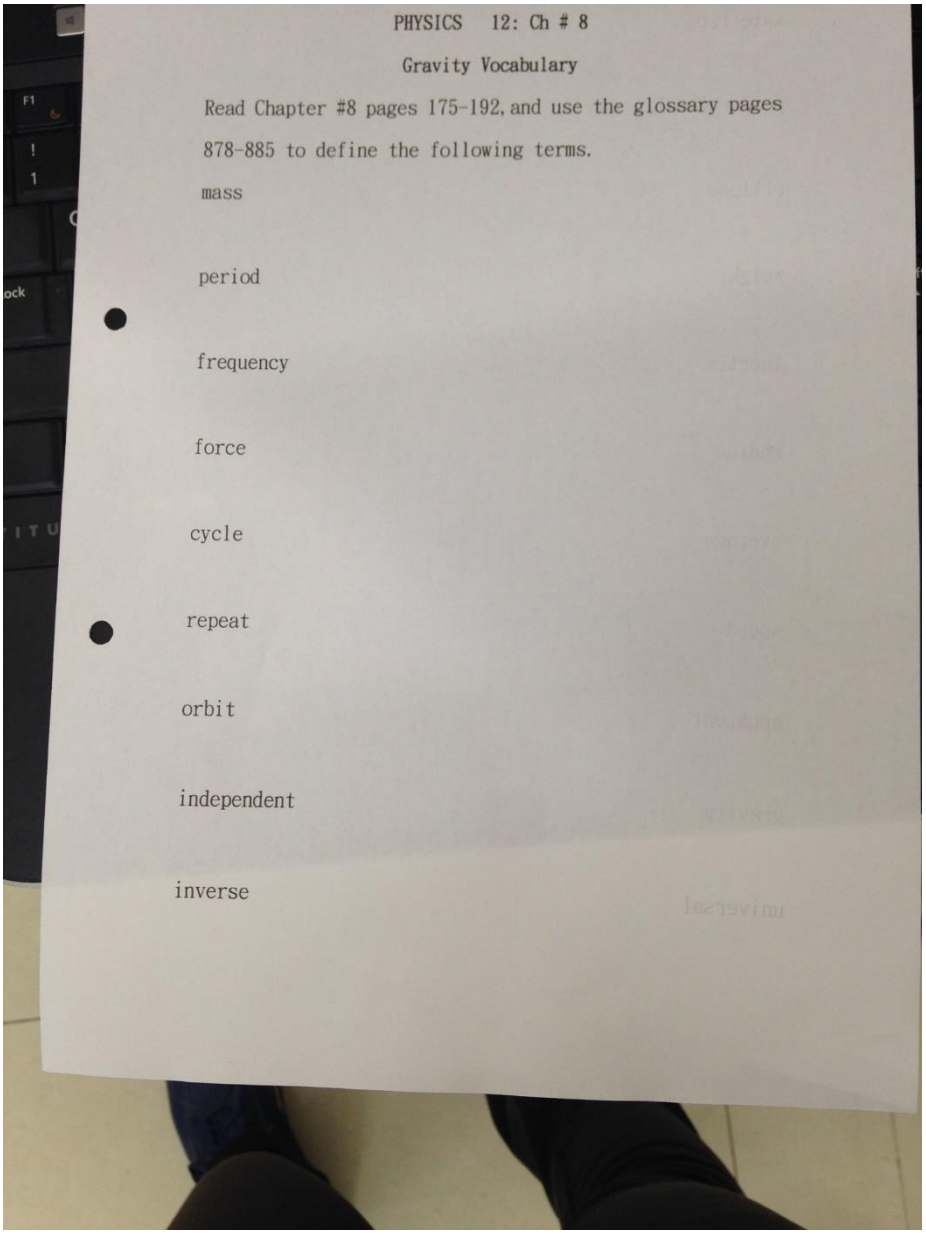
2.Procedural questions

The following example is a case of *procedural questions*, taken from Kate's first Biology lesson. The topic of this lesson was to review the key features of different biomes, such as Tundra, Temperate rainforest, Temperate grassland and so on. The students formed groups of four and each group was assigned two biomes. They were asked to discuss the differences and similarities of these two biomes in groups. This dialogue below took place when the teacher asked a group of students to come to the front and write down their answers on the blackboard for the whole class to see.

Turn	Timespan	Content	Speaker	Ss questions
9	7:36.0 - 7:42.0	Do we need to write or no? Do we write on the blackboard or not?	S4	Procedural question
10	7:39.0 - 7:48.0	*Yea*. And saying! Write and say.	T	

As can be seen above, the student's question in Turn 9 was about procedural concerns about how to proceed with a science task assigned by the teacher, which is writing their own answers on the blackboard. This is not directly related to the science content or language learning.

Appendix 19 Colin's vocabulary worksheet before a new Chapter



PHYSICS 12: Ch # 8

Gravity Vocabulary

Read Chapter #8 pages 175-192, and use the glossary pages 878-885 to define the following terms.

mass

period

frequency

force

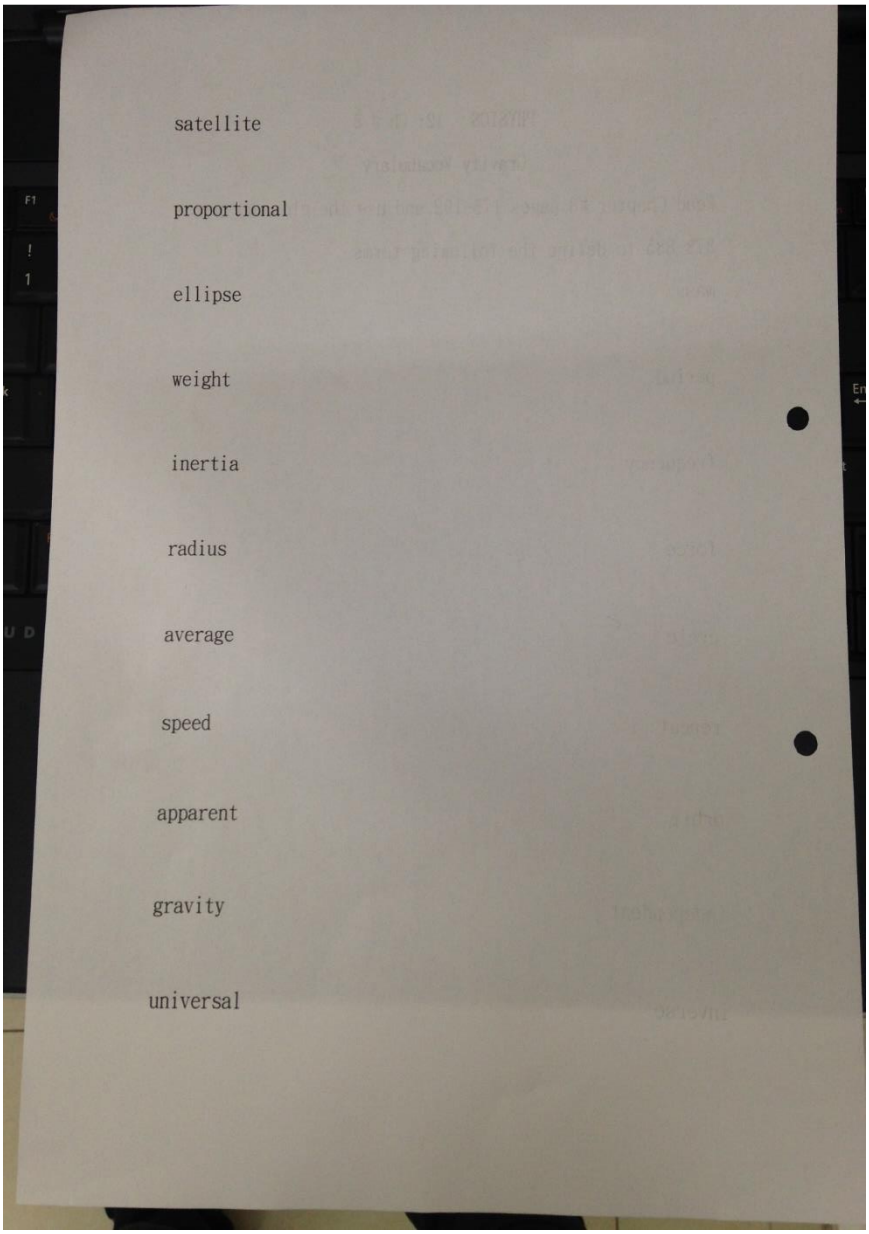
cycle

repeat

orbit

independent

inverse


satellite
proportional
ellipse
weight
inertia
radius
average
speed
apparent
gravity
universal

Appendix 20 An example of the glossary pages in students' textbooks

Glossary

A

absolute zero (12.1): The temperature at which no further thermal energy can be removed from an object; usually shown as −273 °C.
absorption spectrum (28.1): A characteristic set of light wavelengths absorbed by a material, which can be used to indicate the composition of the material.
acceleration due to gravity (5.4): The acceleration of an object in free fall resulting from Earth's gravity.
accuracy (2.2): How well the results of an experiment agree with the measured and accepted value.
achromatic lens (18.2): A lens for which all light colors have the same focal length.
activity (30.1): The number of decays per second, or decay rate, of a radioactive substance.
adhesion (13.1): The electromagnetic force of attraction that acts between particles of different substances.
agent (6.1): A specific, immediate, identifiable cause of a force.
algebraic representation (4.1): Representation of a vector with an italicized letter in boldface type, which is often used in printed materials.
alpha decay (30.1): The radioactive decay process in which the nucleus of an atom emits an alpha particle.
alpha (α) particle (28.1): Positively-charged particles consisting of two protons and two neutrons emitted by radioactive materials.
ammeter (23.2): A device that measures current.
amorphous solids (13.2): Solids with definite volume and shape but no regular crystal structure.
ampere (A) (22.1): The base SI unit of current; one coulomb per second.
amplitude (6.2): The maximum distance an object moves from equilibrium in any periodic motion.
angle of refraction (17.1): The angle the refracted ray makes with the normal to the surface.
angular acceleration (Appendix D, Topic 2): The rate of change of angular velocity for a rotating body.
angular momentum (9.1): Quantity of motion used with objects rotating about a fixed axis.
angular velocity (Appendix D, Topic 2): The angle rotated per unit time, which is usually measured in radians/second; also called the rate of rotation.
antenna (26.2): A device, usually a wire or rod, that generates electromagnetic waves when connected to an alternating current (AC) source.
antinode (14.2): The point of largest amplitude when two wave pulses meet of two superimposed waves.
antiparticle (30.2): A particle of antimatter.
apparent weight (6.2): The weight of an object that is sensed as a result of contact forces on it.
Archimedes' principle (13.1): The buoyant force on an object immersed in a fluid is equal to the weight of the fluid displaced by the object.
armature (24.2): A loop of wire in an electric motor that is mounted on a shaft or axle.
atomic mass unit (u) (30.1): Unit of mass equal to 1/12 the mass of the carbon-12 isotope.
atomic number (Z) (30.1): The number of protons in the nucleus of an atom.
average acceleration (3.3): The change in average velocity divided by time.
average speed (3.3): The ratio of the total distance traveled to the time interval.
average velocity (3.3): The ratio of the change of position to the time interval during which that change occurred.
Avogadro's number (Appendix D, Topic 5): 6.02×10^{23}, which is the number of particles in one mole.

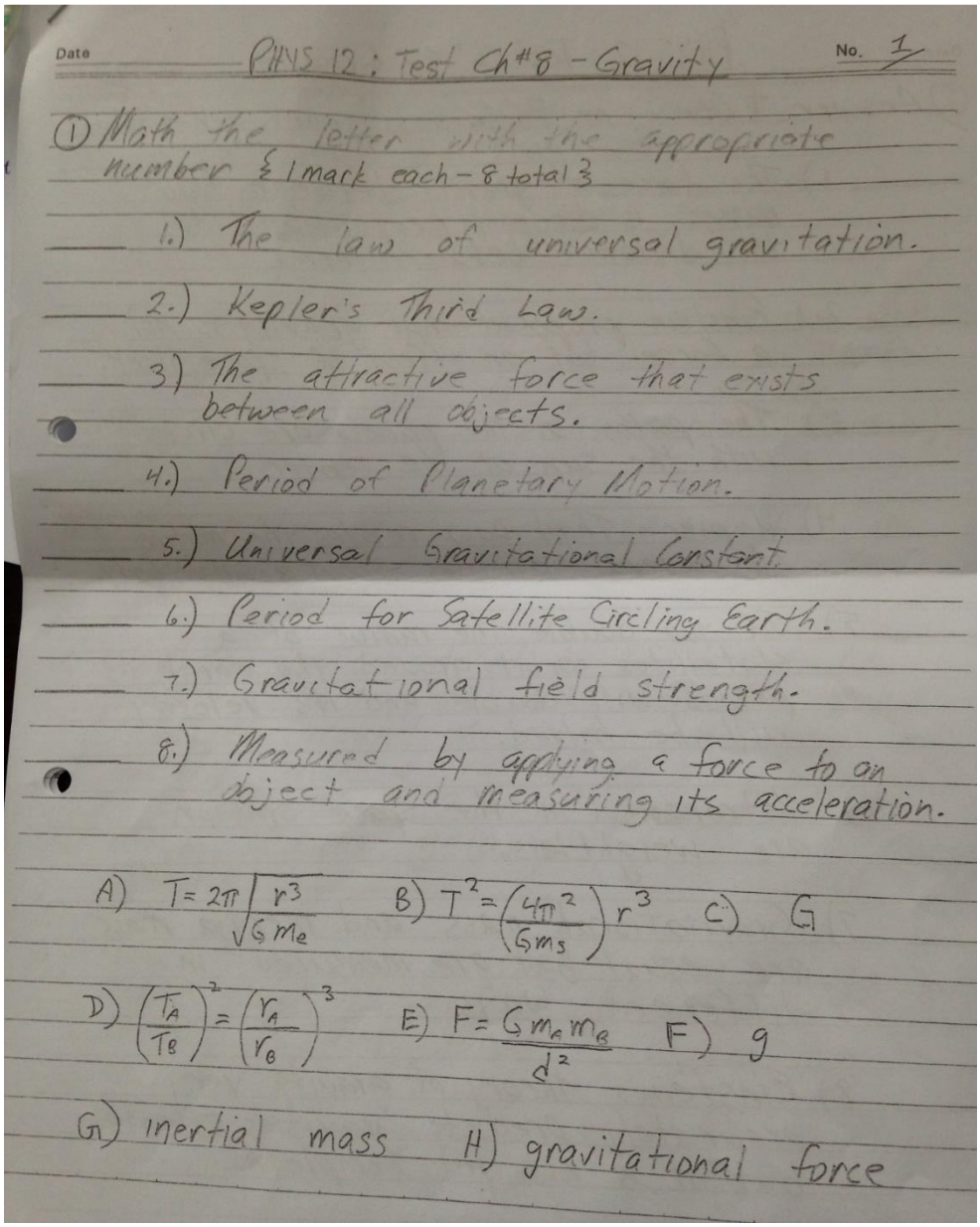
B

band theory (29.1): The theory that electrical conduction in solids can be explained in terms of energy bands and forbidden gaps.
base units (2.1): The seven fundamental SI units of measure.
battery (22.1): A group of several voltaic or galvanic cells connected together to convert chemical energy to electrical energy.
beat (15.2): Oscillation of wave amplitude that occurs as a result of the superposition of two sound waves having nearly identical frequencies.
Bernoulli's principle (13.1): The pressure exerted by a fluid decreases as its velocity increases.
beta decay (30.1): The process of radioactive decay that occurs when a neutron is changed to a proton within the nucleus of an atom, and a beta particle and an antineutrino are emitted.
binding energy (31.1): The energy equivalent of the mass defect; it is converted to thermal energy in a fission reaction.
Bohr model (28.1): A model of an atom with a central nucleus and electrons in specific quantized energy levels from which they can make transitions, emitting or absorbing electromagnetic radiation.
boiling point (12.2): The specific temperature at which added thermal energy causes a substance to change from a liquid to a gaseous state.
Boyle's law (Appendix D, Topic 5): States that for a fixed sample of gas at a constant temperature, the volume of the gas varies inversely with the pressure.
breeder reactor (31.2): A reactor that generates more fissionable fuel than it consumes.
buoyant force (13.1): The upward force exerted on an object immersed in fluid.

C

calorimeter (12.1): A device that provides a closed, isolated system with which to measure changes in the thermal energy of a substance.
candela (cd) (16.1): The SI base unit of luminous intensity; candle power.
capacitance (21.2): The ratio of an object's stored charge to its potential difference; measured in farads.
capacitor (21.2): A device with a specific capacitance that is used in electrical circuits to store charge.
capillary action (13.1): The rise of liquid in a narrow tube that occurs because the adhesive forces between glass and liquid molecules are stronger than the cohesive forces between liquid molecules.
center of mass (Appendix D, Topic 2): The balance point of an object or system that coincides with its center of gravity.
centrifugal "force" (Appendix D, Topic 3): An apparent force that seems to be pulling an object, but does not exert a physical outward push on the object, and is observed only from a rotating reference frame.

Appendix 21 Colin's end of chapter quiz about Gravity



Date PHYS 12: Test Ch#8 - Gravity No. 1

① Math the letter with the appropriate number {1 mark each - 8 total}

1.) The law of universal gravitation.

2.) Kepler's Third Law.

3.) The attractive force that exists between all objects.

4.) Period of Planetary Motion.

5.) Universal Gravitational Constant.

6.) Period for Satellite Circling Earth.

7.) Gravitational field strength.

8.) Measured by applying a force to an object and measuring its acceleration.

A) $T = 2\pi\sqrt{\frac{r^3}{G m_e}}$ B) $T^2 = \left(\frac{4\pi^2}{G m_s}\right) r^3$ C) G

D) $\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$ E) $F = \frac{G m_A m_B}{d^2}$ F) g

G) inertial mass H) gravitational force

Date

PHYS 12 : Test Ch# 8 - Gravity

No. 3

(2) Answer T (true) or F (false): {1 mark each - 8 total}

_____ 1.) The force of gravity between two masses is directly proportional to the distance between them.

_____ 2.) Einstein proposed that gravity is not a force but an effect of space itself.

_____ 3) The paths of the planets are circles with the sun at the center

_____ 4) Kepler's Third Law relates the motion of several satelites about a single body.

_____ 5) If you double the radius of a statellite's orbit around the earth its period will double and it's velocity will be halved.

_____ 6) Astronauts in the space station are weightless.

_____ 7) Gravitational mass and inertia mass are equal but are measured in different ways.

_____ 8) Einstein's theory of gravity very accurately predicts gravities effects but it is not yet complete.

Date PHYS 12: Test Ch#8 - Gravity No. 3.

{one mark each - total 4 marks}

(3) Answer each question with the correct numeric response. Rounding, significant digits and units count. {1 mark each - 4 total}.

a) An asteroid revolves around the sun with a mean (average) orbital radius twice that of earth. Predict the period of the asteroid in earth years. (round to 2 decimals)

ANSWER: _____

b) a satellite orbits Earth 225 km above its surface. What is its period in hours?

ANSWER: _____

c) The sun is considered to be a satellite of our galaxy, the Milky Way. The sun revolves around the center of the galaxy with a radius of 2.2×10^{29} m with a period of 2.5×10^{8} years. Find the mass of the galaxy.

ANSWER: _____

d) How high does a rocket have to go above earth's surface before it's weight is half what it would be on Earth?

ANSWER: _____

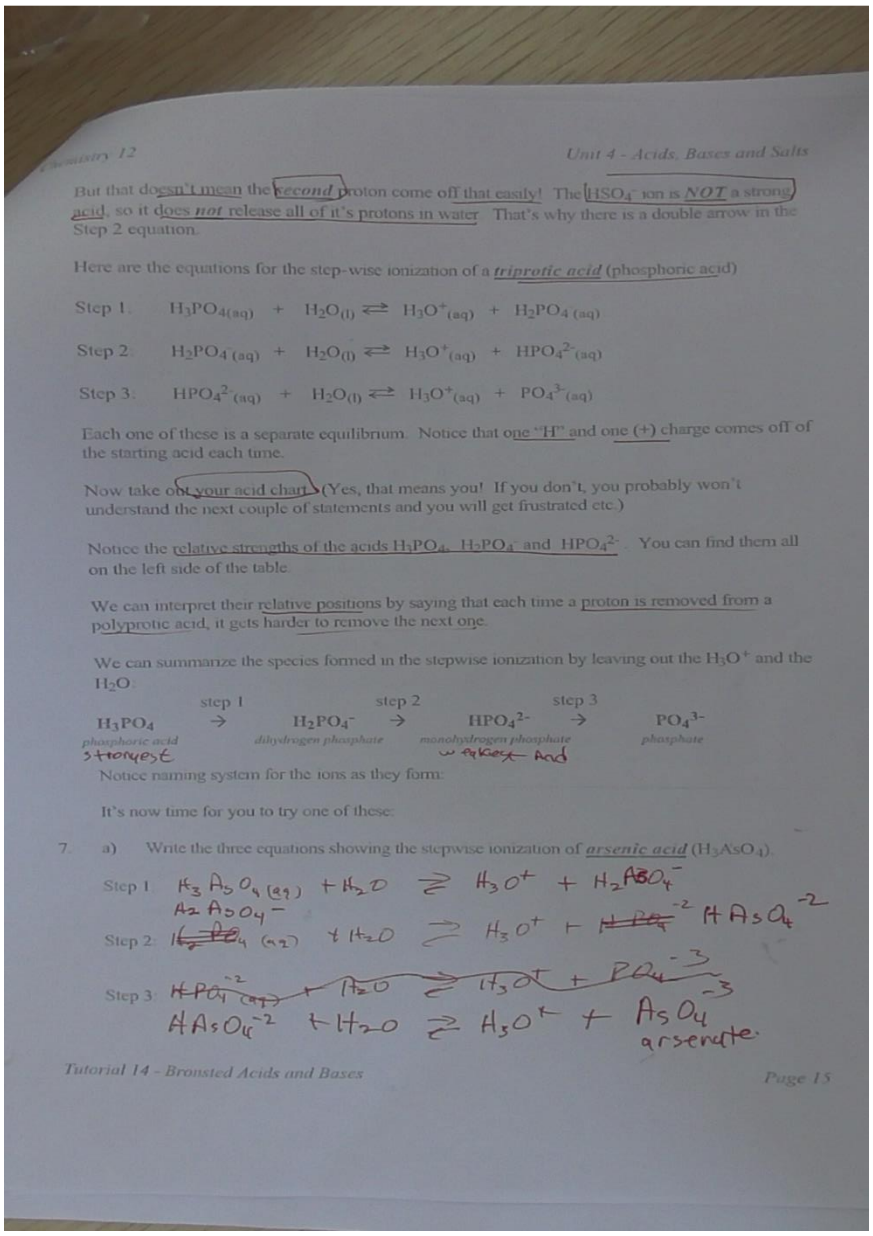
Date

PHYS 12: Test Ch#8 - Gravity No. 4

Extended Response: Show ALL your work.
{5 marks total}

(4) A force of 40.0N is required to pull a 10.0 kg wooden block at a constant velocity accross a smooth glass surface on Earth. What force would be required to pull the same wooden block accross the same glass surface on the planet Jupiter?

Appendix 22 Louis's worksheet



Chemistry 12 — Unit 4 - Acids, Bases and Salts

But that doesn't mean the *second* proton come off that easily! The HSO_4^- ion is ***NOT*** a strong acid, so it does *not* release all of it's protons in water. That's why there is a double arrow in the Step 2 equation.

Here are the equations for the step-wise ionization of a ***triprotic acid*** (phosphoric acid)

Step 1: $H_3PO_{4(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + H_2PO_4^-{}_{(aq)}$

Step 2: $H_2PO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + HPO_4^{2-}{}_{(aq)}$

Step 3: $HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)}$

Each one of these is a separate equilibrium. Notice that one "H" and one (+) charge comes off of the starting acid each time.

Now take out your acid chart. (Yes, that means you! If you don't, you probably won't understand the next couple of statements and you will get frustrated etc.)

Notice the relative strengths of the acids H_3PO_4, $H_2PO_4^-$ and HPO_4^{2-}. You can find them all on the left side of the table.

We can interpret their relative positions by saying that each time a proton is removed from a polyprotic acid, it gets harder to remove the next one.

We can summarize the species formed in the stepwise ionization by leaving out the H_3O^+ and the H_2O:

	step 1		step 2		step 3	
H_3PO_4	→	$H_2PO_4^-$	→	HPO_4^{2-}	→	PO_4^{3-}
phosphoric acid		*dihydrogen phosphate*		*monohydrogen phosphate*		*phosphate*
strongest				weakest Acid		

Notice naming system for the ions as they form:

It's now time for you to try one of these:

7. a) Write the three equations showing the stepwise ionization of ***arsenic acid*** (H_3AsO_4).

Step 1: $H_3AsO_{4(aq)} + H_2O \rightleftarrows H_3O^+ + H_2AsO_4^-$

$H_2AsO_4^-$

Step 2: ~~H_2PO_4~~ $_{(aq)} + H_2O \rightleftarrows H_3O^+ +$ ~~HPO_4^{-2}~~ $HAsO_4^{-2}$

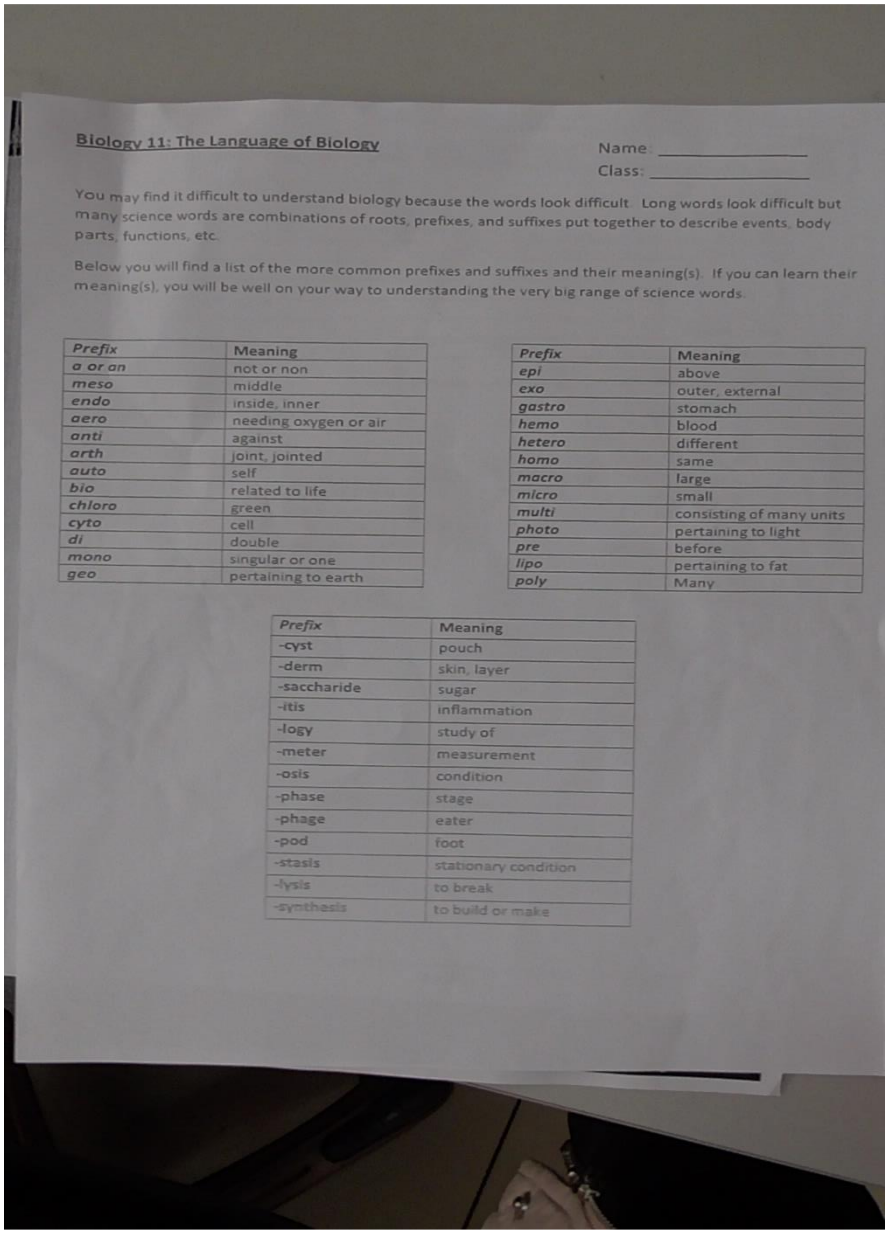
Step 3: ~~$HPO_4^{-2}{}_{(aq)} + H_2O \rightleftarrows H_3O^+ + PO_4^{-3}$~~

$HAsO_4^{-2} + H_2O \rightleftarrows H_3O^+ + AsO_4^{-3}$ arsenate.

Tutorial 14 - Bronsted Acids and Bases — Page 15

Appendix 23 Examples of vocabulary sheets

A vocabulary worksheet given at the beginning of the semester by Hannah:



Biology 11: The Language of Biology

Name: _____

Class: _____

You may find it difficult to understand biology because the words look difficult. Long words look difficult but many science words are combinations of roots, prefixes, and suffixes put together to describe events, body parts, functions, etc.

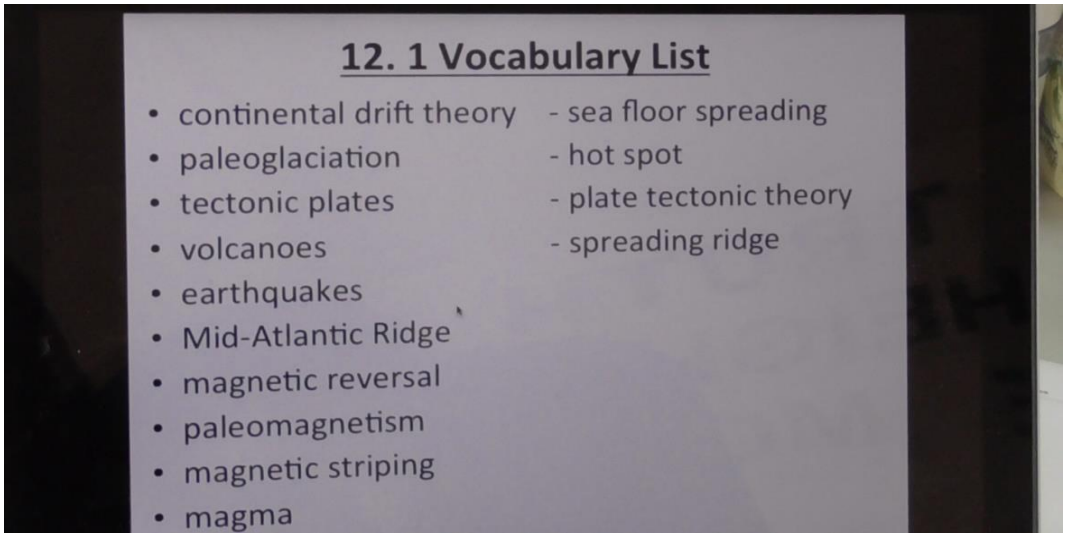
Below you will find a list of the more common prefixes and suffixes and their meaning(s). If you can learn their meaning(s), you will be well on your way to understanding the very big range of science words.

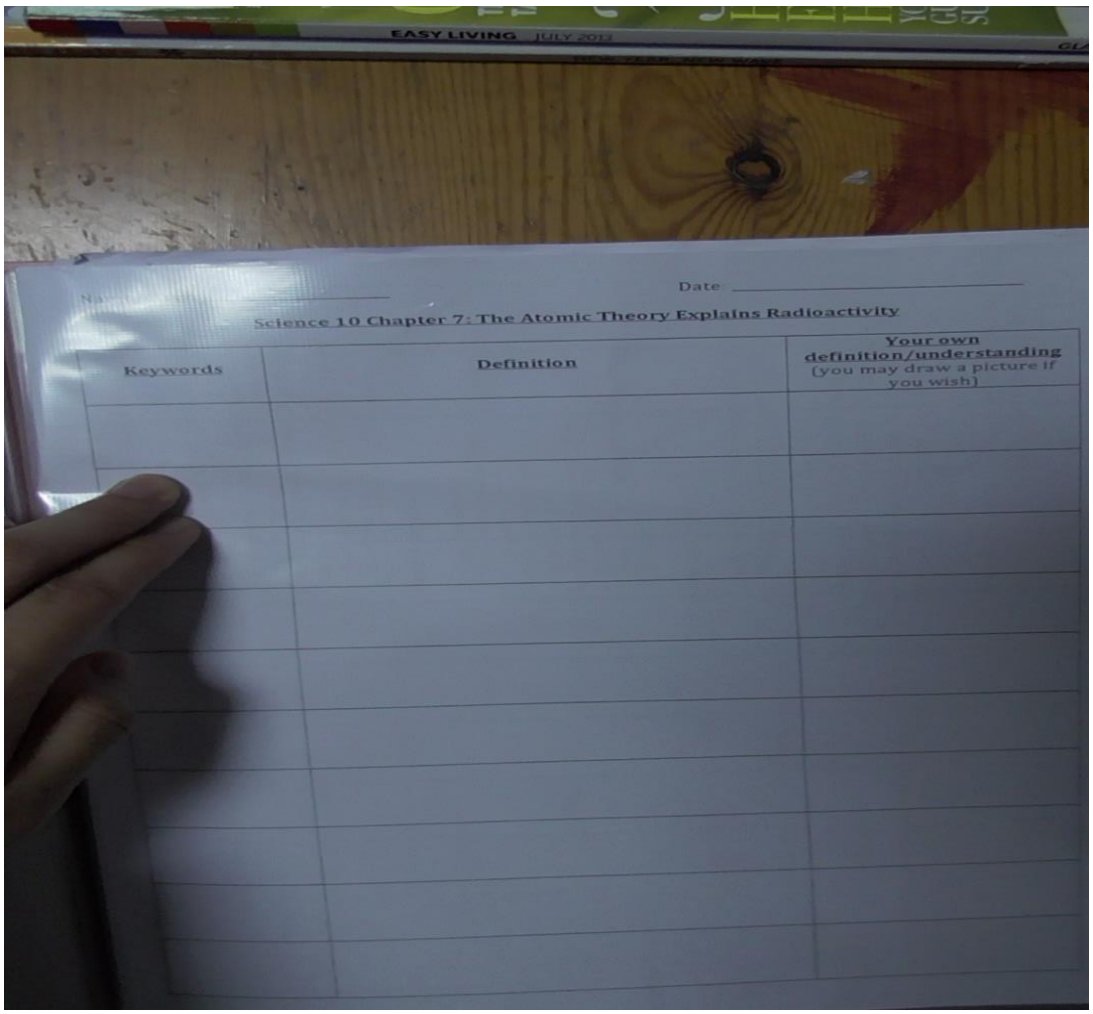
Prefix	Meaning
a or an	not or non
meso	middle
endo	inside, inner
aero	needing oxygen or air
anti	against
arth	joint, jointed
auto	self
bio	related to life
chloro	green
cyto	cell
di	double
mono	singular or one
geo	pertaining to earth

Prefix	Meaning
epi	above
exo	outer, external
gastro	stomach
hemo	blood
hetero	different
homo	same
macro	large
micro	small
multi	consisting of many units
photo	pertaining to light
pre	before
lipo	pertaining to fat
poly	Many

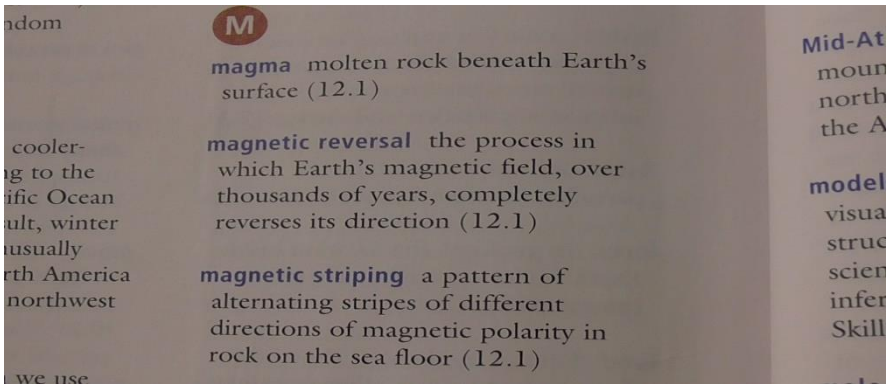
Prefix	Meaning
-cyst	pouch
-derm	skin, layer
-saccharide	sugar
-itis	inflammation
-logy	study of
-meter	measurement
-osis	condition
-phase	stage
-phage	eater
-pod	foot
-stasis	stationary condition
-lysis	to break
-synthesis	to build or make

The list of vocabulary given at the beginning of a chapter by Christina, where students are required to provide explanations by themselves and submit the worksheet below at the end of a chapter:


12. 1 Vocabulary List
• continental drift theory - sea floor spreading
• paleoglaciation - hot spot
• tectonic plates - plate tectonic theory
• volcanoes - spreading ridge
• earthquakes
• Mid-Atlantic Ridge
• magnetic reversal
• paleomagnetism
• magnetic striping
• magma


EASY LIVING JULY 2013
Date
Science 10 Chapter 7: The Atomic Theory Explains Radioactivity
Keywords
Definition
Your own definition/understanding (you may draw a picture if you wish)

Examples of glossary at the back of students' textbooks from Christina's class:



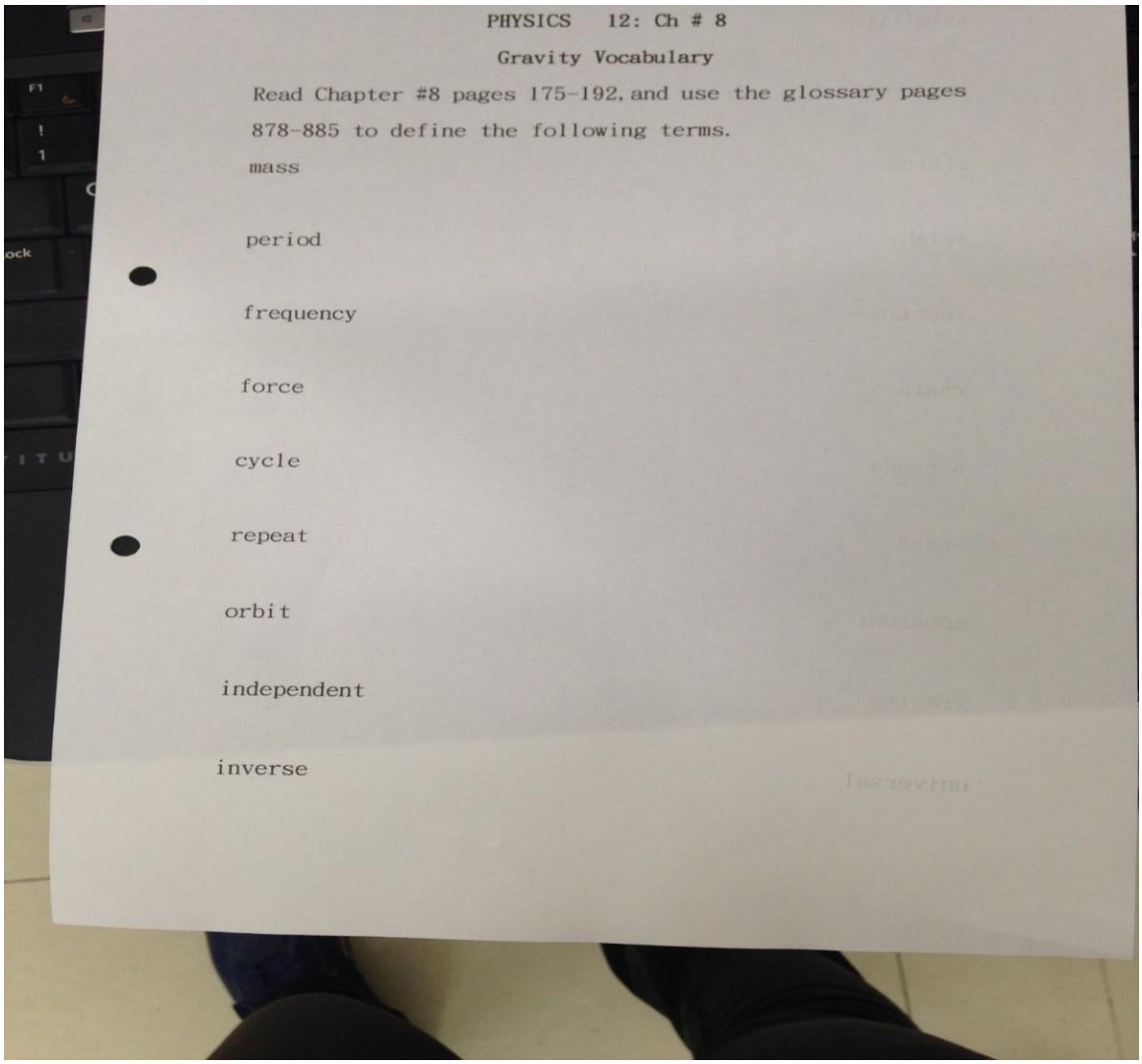
M

magma molten rock beneath Earth's surface (12.1)

magnetic reversal the process in which Earth's magnetic field, over thousands of years, completely reverses its direction (12.1)

magnetic striping a pattern of alternating stripes of different directions of magnetic polarity in rock on the sea floor (12.1)

A vocabulary sheet provided at the beginning of a chapter by Colin:



PHYSICS 12: Ch # 8

Gravity Vocabulary

Read Chapter #8 pages 175-192, and use the glossary pages 878-885 to define the following terms.

mass

period

frequency

force

cycle

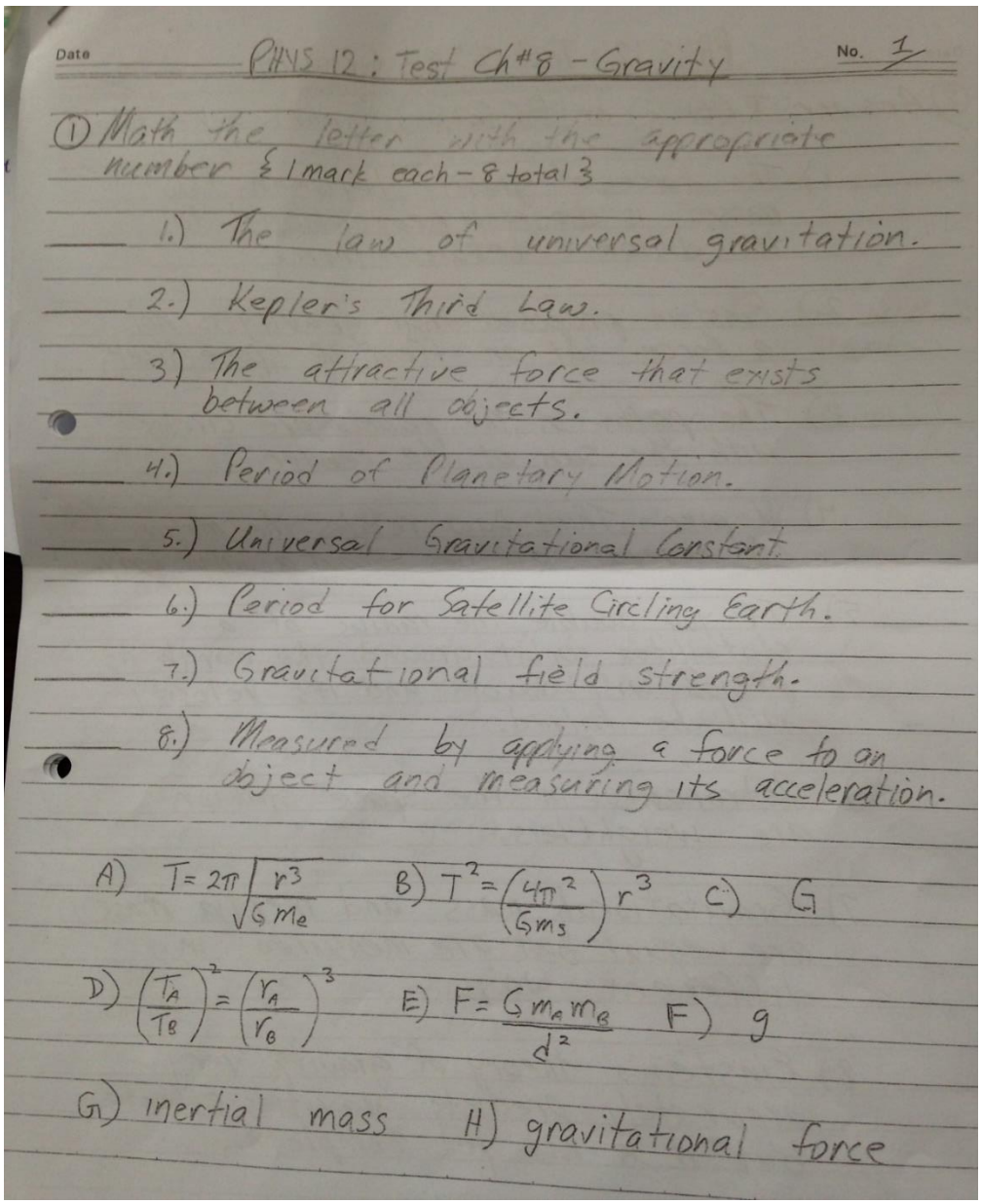
repeat

orbit

independent

inverse

Appendix 24 Language-laden quiz from Colin's first lesson



Date PHYS 12: Test Ch#8 - Gravity No. 1

① Math the letter with the appropriate number & 1 mark each - 8 total 3

1.) The law of universal gravitation.

2.) Kepler's Third Law.

3) The attractive force that exists between all objects.

4.) Period of Planetary Motion.

5.) Universal Gravitational Constant

6.) Period for Satellite Circling Earth.

7.) Gravitational field strength.

8.) Measured by applying a force to an object and measuring its acceleration.

A) $T = 2\pi\sqrt{\frac{r^3}{Gm_e}}$ B) $T^2 = \left(\frac{4\pi^2}{Gm_s}\right) r^3$ C) G

D) $\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$ E) $F = \frac{Gm_A m_B}{d^2}$ F) g

G) inertial mass H) gravitational force

Date

PHYS 12 : Test Ch# 8 - Gravity

No. 3

(2) Answer T (true) or F (false): {1 mark each - 8 total}

_____ 1.) The force of gravity between two masses is directly proportional to the distance between them.

_____ 2.) Einstein proposed that gravity is not a force but an effect of space itself.

_____ 3) The paths of the planets are circles with the sun at the center

_____ 4) Kepler's Third Law relates the motion of several satelites about a single body.

_____ 5) If you double the radius of a statellite's orbit around the earth its period will double and it's velocity will be halved.

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