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Questioning the Sustainability of English-Medium Instruction Policy in Science Classrooms: Teachers' and Students' Experiences at a Hong Kong Secondary School

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Abstract: Teaching science through English as a medium of instruction (EMI) is a growing phenomenon around the world. In Hong Kong, this was realised on a large scale in 2010, with the implementation of a "fine-tuning" compulsory language policy. This allowed Chinese-medium schools to adopt EMI fully. Yet, despite such rapid and widespread adoption, an adequate understanding of key stakeholders' experiences in relation to their perceptions of what constitutes effective EMI science education remains scarce. Thus, we question the sustainability of EMI programs that are driven by top-down policy. In this case study, we explore the perspectives and experiences of six EMI science teachers and thirteen of their students as their secondary school transitions from partial to full EMI. From in-depth interviews (complemented by classroom observations), findings reveal that the transition to full EMI has presented challenges that appear to hinder students' development of scientific knowledge and the language of science in English. This directly counters the primary goal of the fine-tuning policy. Nevertheless, findings also illuminate a number of coping strategies teachers and students use to deal with their changing curricula. Overall, we offer insights into this under-researched context of transitioning EMI programs and provide recommendations for future research and practice.

Keywords: language of science; L2 science education; EMI adoption; translanguaging; language challenges; coping strategies; teacher/student perspectives

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1. Introduction

Teaching subjects such as science through the medium of English is a growing phenomenon around the world. Thus, English as a medium of instruction (EMI) is now internationally recognised in many non-Anglophone nations [1,2]. In many of these countries, EMI is (and has been) swiftly introduced at secondary and university levels with subsequent implications for learning and teaching subject matter in these contexts.

Despite this rapid and widespread adoption across different educational levels and in different subject areas, an adequate understanding of what constitutes effective EMI implementation remains scarce [3]. As Cenoz et al. state, "there are many aspects of the integration of language and content instruction that require careful theoretical, empirical, and pedagogical attention" [4] (pp. 258–259), yet such attention seems to be lacking when it comes to EMI as it "appears to be top-down policy-driven, rather than bottom-up" [3] (p. 64). Although it is an increasing area of interest for researchers, there is little research into how practices and concepts, which are often transferred from established contexts in a decontextualised way, are taken up and used by EMI stakeholders.

The key question at the heart of many discussions on EMI is whether the instructional language and the language of assessment should be exclusively English or English with the students' first language (L1) as a supporting element. The answer to this question has important implications because many of the students admitted to EMI programs may have low proficiency levels in English. As Pecorari notes, "exceptions may be made, less reliable tests may be used to measure proficiency, or alternative experiences (such as prior university study) may be used as a token of English proficiency" [5] (p. 545). Added to these problems is the fact that EMI teachers may be unprepared for such challenges [6], and many currently serving EMI teachers place less emphasis on the development of language skills in their EMI curriculum [3,7]; thus, language learning outcomes are rarely examined or evaluated in EMI classrooms [8,9].

Therefore, with the continual rise in EMI programs around the world and increasing concerns for the effects of rapid EMI implementation, we bring together the perspectives and experiences of six EMI science teachers and thirteen of their students, as their secondary school in Hong Kong transitions from partial to full EMI. Through in-depth, semi-structured interviews (complemented by classroom observations), we explore the challenges these stakeholders face and the subsequent coping strategies they employ when EMI is implemented in their biology, chemistry, and physics classes. We also discuss implications for the teachers and students involved in changing curricula, where the language of instruction becomes a key mediating factor for learning outcomes. Overall, we offer insights into this under-researched context of transitioning EMI programs. We also provide further recommendations for research and practice, particularly as these relate to teaching science through EMI.

1.1. The Teaching Process in EMI Science Classrooms

Previous studies provide inconclusive evidence regarding teachers' views toward EMI [10–13]. While some EMI science teachers believe that they should address students' language issues, many do not accept the dual responsibility of teaching subject knowledge and language [7]. These observations corroborate Dearden's international survey of EMI implementation [9], which found that very few EMI teachers received any form of pre-service training. This is also illustrated by Othman and Saat's case study of pre-service science teachers in Malaysia [13]. In their study, Othman and Saat's participants encountered many challenges, including an inability to integrate content and language, a dearth of dual-purpose materials, and poor English communication skills.

A lack of effective EMI training, in general, is also shown in Yip et al.'s study [12], which examined the quality of instructional activities in Grade 8 science classrooms in Hong Kong. They found limited English proficiency among their teacher sample, constraining their ability to explain abstract and complex scientific concepts through English, as well as hindering teachers' deployment of more complex questions, such as higher-order and conceptual change questions. In a follow-up study, Yip found many of the EMI biology teachers he sampled were also not adept at complex forms of questioning [14]. They also struggled to make use of students' prior experiences and existing knowledge and thus did not engage students beyond simple recall questions, which have lower cognitive demand, and were primarily used to accommodate the language challenges in their classrooms.

These findings resonate with studies in similar contexts, where unsystematic teaching practices occur. In Wong's study, for instance, EMI teachers utilised high amounts of closed and recall questions, which resulted in authoritative, transmission-based teaching, with little space to learn complex ideas from more constructivist theoretical perspectives [15] (see also [16]). Similarly, in Malaysia, Yassin et al. observed that EMI science teachers mainly used close-ended and low-cognitive demand questions such as "what is the name of this planet?"—a type of fact-recalling question—due to limited English ability [17]. More importantly, though, pedagogical constraints resulting from EMI (e.g., questioning techniques) have been shown to have a negative impact on teacher–student interactions and thus may prohibit students' content learning [18,19].

Such studies also indicate that EMI science classrooms in Hong Kong generally align with a monologic approach to teaching. While it is understandable that some EMI science teachers would use low-cognitive demand questions as a coping strategy, because they reduce language demands and cater to students' limited English proficiency, extensive use of less cognitively demanding questions may indirectly promote rote learning [20]. Hence, a monologic teaching style raises the question of how EMI impacts teachers' explanations, interactions with students, questioning skills, and awareness of students' English needs [18,21].

1.2. The Language of EMI Science Classrooms

The students in EMI science classrooms face a double challenge in learning science through English: They must develop not only scientific knowledge but also a level of English that is necessary to read and write scientific ideas [22]. However, the language of scientific English is vastly different from everyday English [23]. This is because it has evolved to represent complex, dynamic activities (events and relationships) and synoptic entities (items) that can be quantified, evaluated, condensed, and manipulated in complex ways, "transforming the flux of experience into configurations of semiotic classes" [24] (p. 197).

At the word level, these semiotic classes are composed of concrete entities and abstract concepts (static items) that are organized in complex taxonomic relationships of composition or classification [25]. At the clausal level, scientific phenomena are construed dynamically, represented as implicational or expectant outcomes that can be cyclical, culminative, or unending, and related to other fields of activity in terms of interdependency relations such as extending, enhancing, or elaborating [26]. Adding to this complexity is the fact that combining these meanings into cohesive, coherent texts in writing calls upon a number of highly developed mechanisms [27]. Hence, to master scientific knowledge, EMI students need to be able to both understand and manipulate intricate epistemological constellations of meaning [28]—and do so in a language that is not their L1.

The differences between students' first language and English may also be a source of confusion. The physics students in Fung and Yip's study, for instance, found it difficult to make distinctions between specific scientific concepts in English because Chinese does not make distinctions in the way English does [29]. The word "heat" is provided as an example, since Chinese uses the same word for both "heat" and "hot". Given that students from Chinese-medium schools in Hong Kong begin to adopt EMI at later stages of their secondary education, it is vital to explore these students' views toward the type of English that is required for learning science through EMI. It is also important to determine whether these students have similar language challenges as their counterparts in early-full EMI schools.

1.3. Comparing EMI and L1 Students' Academic Results

An increasing body of research suggests that EMI has a significantly negative effect on students' achievement levels when compared with students in L1 classrooms. Amaechi, for instance, interviewed students in three junior secondary schools in Nigeria and reported that EMI students preferred dual language instruction in English and Igbo [30]. They perceived this as a more effective approach to access content (see also [31]). Similar findings can be seen in the United Arab Emirates [32], Thailand [33], and Slovakia [34], where it was found that English may constrain students' ability to express the knowledge that they have in their L1 (see also [21,35]).

Moreover, English language skills developed in primary school may not be sufficient to master scientific content at later levels [36]. For instance, Yip et al. examined the extent of EMI on students' academic achievements in Hong Kong [12]. Students from 100 EMI classrooms were compared with students in Chinese-medium instruction (CMI) schools with the same level of academic achievement prior to entering Grade 7; their academic achievement (in mathematics and science) from Grades 7 to 9 were measured. Results showed that EMI had a significantly negative effect on students' initial academic achievement in terms of performance on science tests and their understandings of abstract concepts, distinguishing scientific terms, and applying scientific concepts to different situations [12]. However, given the limited length of time over which data were collected, it is unclear when, and how, such a disadvantage is offset at senior levels, if at all. It is also unclear how these students' English proficiency and scientific knowledge developed after Grade 9.

The negative impact on science-related achievement has also been observed at senior secondary levels, but the disadvantage of learning science through English is often offset to an extent through students' increased English proficiency at these upper levels and/or possibly because they are more familiar with EMI [21]. This is evidenced in a classic study on the effect of MOI on physics achievement for Grade 10 students in Hong Kong [37]. Ho found no difference in learning achievement between a CMI group and an EMI group; however, the latter had received formal science instruction through EMI for at least three years and, therefore, had time to adjust. Fung and Yip's more recent study of Grade 10 physics students in Hong Kong, meanwhile, suggests that learning achievement is affected by MOI for low-ability students, who performed better after receiving CMI, and high-ability students whose performance was most enhanced by EMI [29].

1.4. EMI in Hong Kong

There are two types of EMI schools in Hong Kong. The first is called early-full EMI and is found in secondary schools that adopt full EMI from Grades 7 onward. Early-full EMI schools are where both instructional language and learning materials are in English, and teacher–student interactions occur primarily in English. The second type is late-partial EMI, which are essentially mixed language schools [38], where classes are mainly CMI but adopt partial EMI at the senior secondary level from Grades 9 to 12. Although teaching and exam materials are written in English, teachers and students in these schools interact mainly in Cantonese.

In 2010, a "fine-tuning" language policy was introduced in Hong Kong, which saw CMI schools implement EMI at the senior secondary level (e.g., Grades 9–12). One of the aims was for students to develop English-language proficiency by studying content courses in English [39]. During the early stages of the "fine-tuning" policy, Chan explored stakeholders' perspectives on policy implementation in one medium of instruction (MOI)-switching school [40]; Chan reported that an increased amount of EMI teaching resulted in many language challenges related to writing and reading in content subjects, but that there may have been greater challenges for the students in the late-partial EMI schools due to their limited English abilities and experiences. Indeed, in earlier studies, students sometimes found that what they wrote in English in their examinations did not match what they could express in spoken Cantonese [12,36].

Chan argued that the increased amount of EMI under the new policy only "benefited the more capable students but sacrificed the interests and learning needs of less able students" [10] (p. 459). This sentiment was echoed by Poon et al., who surveyed 461 first-year secondary school students on perceptions of EMI policy at their school [41]. Although at least half of the students preferred to be placed in EMI classrooms, the majority of students did not favour the use of EMI because they encountered numerous language difficulties when switching from Chinese to English.

Although they emphasise negative feelings toward EMI adoption, Chan [10,40] and Poon et al. [41] provide little evidence on how EMI was actually implemented, to what extent English was used, and how teaching and learning were shaped by the use of English during the early stages of transition in the MOI-switching secondary schools. Hence, the extent to which EMI is operationalised to benefit students in MOI-switching schools, which may be different from early-full EMI schools, is questionable. Furthermore, it may not be sustainable. Although the fine-tuning language policy has been implemented for nearly ten years, there is little evidence that adopting EMI at the later stage of senior secondary levels is beneficial for students' learning. Therefore, it is vital to explore the views of stakeholders in these Chinese-medium schools that changed to EMI to reveal their challenges.

The present case study aims to investigate not only the views of the teachers and students during their transition from partial to full EMI at the senior secondary level but also some of the challenges they faced and the coping strategies they used in their EMI classrooms. This study aims to address the following research questions.

1. What are the perceptions of teachers and students in an MOI-switching school toward EMI for senior secondary school science subjects?
2. What are their reported language challenges and coping strategies in the transition from CMI to EMI?

2. Methods

2.1. Research Context

The selected school was part of a larger study that used stratified sampling based on Hong Kong secondary schools' official MOI, location, curriculum, and academic performance (in content and in English) (see [22,42]). The school was chosen because it is representative of a "typical" school within this context (i.e., it is a government-run, former CMI secondary school that began transitioning to EMI in 2010 that may serve as a representative case). Most students in this school are from working-class families and are categorised as Band 1. This suggests that they have average or above-average academic achievement and that their English ability has passed a suggested threshold level. According to the Hong Kong Education Bureau, this makes them eligible for EMI immersion at senior levels.

2.2. Participants

As a case study at the institution level, we contacted the school's science teachers to inform them about the study, focusing on a somewhat even spread across physics, biology, and chemistry teachers. This resulted in a purposive sample of six science teachers and thirteen of their students from Grades 10 and 11. The students, who were randomly selected for interviews following observed lessons, were between 15 and 18 years old, with an even number of students in Grades 10 and 11. Eighty-five per cent of students were studying physics, chemistry, and biology. The participating teachers were all male, and none had received EMI training. Due to the heterogeneous nature of their backgrounds, we present our teacher demographics in Table 1.

Table 1. Teachers' demographic details.

Teacher's Code	T1	T2	T3	T4	T5	T6
Age range	31–40	51–60	31–40	41–50	41–50	51–60
University degree	Biology	Chemistry	Chemistry	Physics	Physics	Biology
Total years teaching	6	40	11	19	15	35
Total years teaching in EMI Schools	6	35	4	19	15	35
Average self-reported English ability across listening, speaking, writing, and reading skills	3.75	3	3	3.25	3	4

Note: self-reported English levels: 1 (poor) 2 (fair) 3 (moderate) 4 (good) 5 (excellent).

All participants were asked to complete a consent form before data collection. Parents were also asked to sign a consent form if their children were younger than 16 years old.

2.3. Data Collection and Preparation

Classroom observations of at least two lessons for each of the school's six science teachers were conducted by the first author. Descriptive field notes included information pertaining to lesson structure, pedagogy, interactions, classroom climate, and other aspects deemed relevant to understand teachers' and students' EMI experience. Video-recorded observations were analysed in-depth and reported elsewhere (see [42]). In this article, we draw on the researcher's observations as ancillary data to substantiate information shared by the participants.

Semi-structured interviews were conducted with all six of the school's science teachers: once before their first observed lesson and once after. Since the teachers had already completed a background questionnaire, where general information was gathered, pre-observation interviews focused mainly on the soon-to-be observed lesson (e.g., aims, intended outcomes, etc.). Post-observation interviews were conducted with the teachers to follow up on what actually occurred during the lesson and included questions related to observed teaching practices, challenges, and coping strategies. Interviews lasted approximately 30 minutes. Thirteen students were also interviewed. They were randomly selected from three different classes (Grade 10 biology, Grade 10 chemistry, and Grade 11 physics) following the observed lessons. They were interviewed in small groups, with 2–3 participants per group. All interviews were conducted in Cantonese, the participants' first language.

Interview questions were adapted from pilot interview protocols, which were developed during doctoral research in Hong Kong [22]. The interviews aimed to elicit student and teacher views on and experience with EMI in this context, as well as the challenges and coping strategies they used. The interview questions (see Appendix A) were checked by a bilingual researcher with experience in training local teachers, and a science teacher was consulted on the final version before data collection. The recorded interviews were transcribed verbatim and translated from Cantonese to English by a bilingual researcher for content analysis.

2.4. Data Coding and Analysis

Using a two-step coding process for in-depth qualitative analysis (see [43]), each transcript was analysed with open codes for patterns or recurrent themes related to the research questions (i.e., views on EMI, language challenges, and coping strategies). The coded transcripts were then carefully read and repeatedly compared, sorted, recoded, and explored for connections among the coded segments. Two independent raters checked the reliability of approximately 10% of the data and established good inter-rater reliability ($k > 0.8$) with Cohen's kappa coefficient.

Moreover, in line with a number of recent studies exploring the challenges of teaching and learning in EMI settings, we further analysed our coded segments for the positions taken up by our participants (see [44,45]). More specifically, through the lens of Positioning Theory [46], we were able to delineate further our participants' beliefs, challenges, and coping strategies with respect to their acceptance/rejection of macro- (institutional), meso- (classroom), and micro-level (individual) constraints and affordances.

3. Results and Discussion

3.1. Perceptions of Teachers and Students toward EMI for Science Subjects

3.1.1. English in the Classroom

At the macro-level, teachers generally positioned themselves as accepting their institution's implementation of EMI. At the meso-level, however, most teachers rejected the blanket use of English and strongly felt that there should be a choice regarding the use of L1 in classrooms. Moreover, five out of six teachers stated that the majority of science teachers do not speak English well, and thus they should be allowed to use their L1 to some degree. We find this somewhat surprising, because at the micro-level of the individual, the teachers we sampled are positioning themselves and their colleagues in general, as resisting the role that advanced English proficiency plays in EMI programs. Fundamentally, although many of the teachers have worked in EMI schools for decades (see Table 1), there seems to have been little effort to raise their proficiency in English to a level that they imply is needed to teach science through English—their combined self-reported English language level was just slightly above "moderate" ($M = 3.33$). Incidentally, all the teachers believed that there is a school-based MOI policy that allows for "optimal" use of the L1 in EMI teaching, yet they were unsure as to what optimal actually was. Field notes from the classroom observations indicated that judicious use of L1 was indeed present and that such use, in fact, seemed appropriate and helpful for the students to understand complex science content.

Moreover, for the teachers in this study, we believe that EMI may be a labelling effect because most of them believed that they used English only to transfer knowledge, rather than to help students learn English in scientific areas. For instance, most teachers believed that they delivered lessons in English without much attention to students' English needs; as one teacher stated, "I don't think learning physics through Chinese impacts students' content understanding in English as we focus on concepts. Regarding the aspect of using English, it's just about learning the terms. Also, we don't assess their writing ability per se. So, the use of language doesn't make a big difference" (T4). This accords with recent research into teachers' perspectives on EMI in Japan and China, where teachers primarily saw EMI as "an instructional approach to content learning, rather than as a tool for learning English" [7] (p. 33). This also aligns with Block and Moncada-Comas's conception of EMI teachers positioning themselves as being *not* English language teachers (ELTs) [47] (see also [44,48]).

Nevertheless, it is also interesting to note that although the teachers in our sample shared this positioning, their beliefs also reflected the absence of a language learning outcome in their curriculum. We would argue that they are, in essence, aligning with the EMI gaze within the shaping structures of their institution (see [2,47]); namely, the discursive formation at the institutional level of the school (i.e., the framing of a curriculum unconcerned with language assessment) is actually legitimising their positions as not language teachers [44]. Hence, by enacting EMI through their policy documents in such a way, this school is, albeit implicitly, (re)enforcing their teachers' beliefs that language learning is not a concern in their classrooms. Clearly, how an institution frames EMI curricula have important implications for how EMI is taken up and seen by stakeholders; this is especially true with regard to the importance given to language accuracy in assessment rubrics, wherein students and teachers often have different beliefs about what is being assessed, and thus orient toward different goals and practices [49].

The students, on the other hand, generally saw EMI as an opportunity to improve their English rather than a demotivation to learn science. However, nine out of thirteen students showed concern for the use of English in learning science due to their perceived low-level proficiencies. One student noted, "The words are difficult to understand, and it is difficult to use some technical verbs". This quote highlights one of the key issues that emerged throughout the interviews, namely, the centrality of vocabulary in building shared understandings. As to not belabour the point both here and elsewhere, we return to it in more detail below.

3.1.2. Cantonese (L1) in the Classroom

When asked about their preference for instructional language, teachers generally welcomed a mixed-mode, with Cantonese as the primary language and English scientific terms embedded within it. In their view, the use of the L1 in EMI classrooms can help teachers explain abstract scientific concepts and make conceptual relationships more explicit to students. With the L1, teachers believed that they could easily accommodate a group of students with diverse abilities in both science and English, as well as help their students consolidate scientific thinking by making connections between what students previously learned and what they see in daily life. For instance, one teacher drew attention to lower English proficiency students who may excel in subject knowledge in Cantonese and remarked, "I think the motivation or benefit is that they can have more choices, because you can never force weaker students to adapt 100% to English" (T3). Through using the L1, students can bridge the gap between how they conceptualise in the L2 and how they conceptualise in their L1, as well as between what they are able to understand and articulate in the L2 more easily [19]. The use of the L1 also facilitates students to explain abstract ideas and logic, consolidate their scientific knowledge, and think deeply [42]. In this light, our teachers seem to be positioning themselves as fluid and adaptable, aligning their teaching methods and the use of English to the needs of individual students. However, they are also aligning themselves more firmly with content learning goals than language learning goals, thus once again positioning themselves as not ELTs.

The students, on the other hand, noted that one possible consequence of relying heavily on the L1 in an EMI science classroom is that they forget the scientific terms or expressions in English, especially those students with limited English. Thus, despite many students also preferring a more flexible MOI school-based policy—one which allows the use of Cantonese and English in EMI classrooms—they also show awareness that too much L1 might be detrimental to their learning English. Hence, they appear to be positioning themselves in a slightly different way to that of their teachers. Namely, students see the importance of learning English and thus align themselves as wanting to develop both content knowledge and English language proficiency.

Interestingly, the students also reported that more Cantonese is spoken in biology and chemistry lessons than in physics lessons, which may be due to the language-rich environments of such subjects that emerge during experiments. For instance, translanguaging was found to be a favourable approach for conducting science (biology and chemistry) laboratory sessions. Translanguaging is defined as "the exploitation of multiple languages and semiotic resources in a multilingual repertoire", which, in this case, helped to facilitate students' joint process of knowledge construction and promote their acquisition of scientific concepts [50] (p. 2). It may well be the case, then, that EMI policy for STEM subjects could be taken up and implemented differently not just in individual teacher–student interactions but also in different subject fields. This would have clear implications for the amount of language support needed in different STEM subjects.

Students with limited English also stated that they tried to first organise their thoughts in their mother tongue (Cantonese) and then translate them into English. The students called the result of these translations *Chinglish*: "For me, I will use English to express myself if I can. If I can't, I will use Chinglish". Students with limited English skills felt that this was an efficient way to express scientific ideas. Another student stated, "I try to use English if the situation is okay. And if it doesn't work, I mix Chinese with English". Field notes from the classroom observations noted several instances in which "Chinglish" was used by the students, directly linking their expressions in the interviews with what actually occurred in the lessons. This mixing of L1 and L2 reflects students actively engaging in learning science through English by taking ownership of English for their own purposes [51].

4. Reported Language Challenges in Switching from CMI to EMI

Analytical Expressions and Communication Skills

The teachers reported that their students encounter many language challenges when learning science through English. Two of these challenges were poor analytical expression and communication skills. One biology teacher (T1) stated, "My students understand the science concepts but often can't express their ideas and logic accurately. I believe this is due to their poor English and lack of adequate vocabulary to describe abstract science concepts". He remarked that although he knew his students fully understood the ideas when marking their papers, many could not produce an adequate explanation or argument due to language constraints. The teacher added that there is a strong relationship between language and the ability to organise logical thoughts in science. Once again, these teachers seem to be positioning themselves as not language teachers. Fundamentally, they are clearly aware of language-related problems that could affect their students' grades, yet they seem to show little concern for actually helping them address these issues. To us, this is somewhat unsurprising given the teachers relatively low self-reported levels of English ability, as we question whether they would be able to provide detailed language support if asked to do so by their institution. Indeed, field notes from the classroom observations made reference to certain instances where teachers themselves seemed to struggle to communicate an idea in English.

In terms of oral communication, the teachers generally believed that the students were also limited in terms of presenting science ideas verbally. One teacher remarked, "Students can't express what they want. The technical terms are too difficult, so they don't know how to use them . . . the students know the terms in Chinese but don't know how to present them in English . . . they are not used to speaking English" (T6). This suggests that students' limited oral proficiency is due not only to their lack of experience in speaking English but also to problems in translating complex taxonomic relationships into English. Essentially, we believe it goes beyond simply being "not used to speaking English". As Martin highlights, specialised knowledge (or vocabulary) in science goes beyond ostensive definitions, "as scientists develop alternative ways of classifying and composing the world and explaining change along many scales of time" [25] (p. 122). These ways of "knowing" are "learned through mentoring, apprenticeship, training, coaching and initiating" [25] (p. 120), which are more often than not done in a person's L1. Thus, while T6 is somewhat correct in his assumption, we question how learners could gain such deepened knowledge of science in English given the limited time they spend with EMI.

As elaborated in the next section, some of the less proficient students reported that they do not spend time learning how to write scientific texts in English, and that they were not explicitly taught this skill in their science classrooms. Indeed, such instruction was not present in the observed lessons (a caveat being that only two lessons per teacher were observed). Instead, students memorised lengthy sentences to describe a scientific phenomenon in their examinations. Such rote memorisation has been observed in many MOI-switching schools in Hong Kong [20], and it has created problems when these students attempt to explain or elaborate on scientific concepts in English. One teacher noted, "Students copy everything from the textbook when answering questions. This is because the students are used to the learning style in junior forms . . . I remind students and encourage them to critically analyse science phenomena" (T2). This type of learning approach (rote learning from texts) may impede students' progress in attempting to comprehend and use scientific English in a more meaningful and authentic way.

The students also seemed to share a similar view with their teachers regarding language challenges in areas such as communicating and analysing science topics in English. Eleven out of thirteen students had concerns about their reading and writing abilities. Students had frustrations with these two aspects because they could not recall key concepts when writing scientific explanations during a test. Other students thought that they would be able to better convey scientific ideas in Cantonese first and then re-write them in English, but they reported that there was often a gap between their thoughts and the English expression of these thoughts.

We see such translation of ideas between L1 thoughts and L2 writing as particularly challenging in EMI classes. This is because networks of non-linear thought patterns, which are perhaps fully developed in the L1, need to be transformed into linear, sequential arrangements in the L2, where the organization of text and "pointers" within that text tell the reader where to look for connections. Clearly, this calls upon a high level of ability in L2 writing (as noted in the literature review) and raises the question of how representative the students' final text is in relation to what they had actually conceptualised in their minds.

The students with limited English also reported that they produced explanations through rote memorisation. This approach echoed their teachers' concerns, whereby students have difficulty understanding key scientific words and thus try to memorise sections of their textbooks by writing, word-for-word, what they have read. While this may be helpful in some activities, it does not always work for spontaneous communication. For instance, when one student was asked by the first researcher what she would do if asked to write an observable result from a recently completed lesson, she responded, "I would use the simplest expression, 'This is zinc' [in English], rather than 'In this experiment, zinc was generated. We observed that a metal layer was formed, and that metal was zinc' [in

Cantonese].” This is clearly problematic, as uninformed or unsympathetic teachers may interpret the short response in English as lacking care or understanding. In reality, the issue is the student’s lack of communication skills in English, especially as they relate to the dynamic construal of epistemological constellations of meaning (see [26]).

5. Depth and Breadth of Vocabulary Knowledge

The teachers commented on three types of vocabulary with which students encounter problems when learning science: “basic” English vocabulary, academic vocabulary, and specialised scientific vocabulary. The teachers all admitted that their students have problems with “basic” English vocabulary because they are often not familiar with it. One teacher remarked, “I think they have no problem in handling technical terms, as we will teach them anyway. The problem is handling simple English words, as students don’t usually see them. I don’t think I can help much, but maybe they can do more exercises to learn more words” (T1). This view accords with recent literature that highlights the ELT positioning of some EMI teachers who emphasise a focus on vocabulary but do not go beyond a limited focus on language specifically related to their field (e.g., [52,53]).

Another chemistry teacher made a similar remark to T1 (above), noting that “my students do not have [any] grammar problems, but they can’t understand words in simple English, for example, ‘account for’ … ” (T3). While individually these lexical items may appear “simple”, phrasal verbs such as “account for” (and other multi-word constructions) take on slightly different meanings when combined and are signs of more proficient English language use [54]. This may be what these teachers are referring to in terms of students not knowing or misunderstanding “basic” vocabulary. Hence, such issues may also be reflective of the teachers’ limited knowledge of the nuanced nature of many English constructions and highlight the need for EMI teachers to have at least some basic training in ELT, despite their resistance to position themselves as language teachers (see above).

The teachers also indicated that their students mixed up specialised scientific vocabulary and its meanings in different contexts. They believed that this reflected students’ poor awareness and unclear understandings of similar concepts, such as “strong bonding” and “giant structure” in chemistry. The teachers added that a major consequence of having poor vocabulary knowledge is a negative impact on students’ communication skills, in both spoken and written modes, especially when students are asked to write an essay to explain a scientific phenomenon. Again, we do not necessarily see this as an issue with the denotative nature of individual word meanings per se, but with the nuanced nature of collocational constructions and language usage. The meanings of such combinatory units are perhaps best learned through repeated exposure in use, yet the positioning of our teachers as not ELTs would not help in this regard, as perhaps they merely present the concept once and move on.

The students reported a similar view on vocabulary challenges. First, the students stated that they struggled with certain words used in questions and hence did not know what kind of answer to give. For example, for words such as “account”, “analyse”, and “exemplify”, some students said that they misinterpreted these words as asking to show a calculation rather than producing a narrative to describe and explain something. Second, the students said that they have problems with unfamiliar vocabulary for learned science topics, such as the name of a disease, bacteria, or chemical compound. One student said that he learned the word “acetylsalicylic acid” from his textbook but did not know the equivalent, generic term in English (aspirin) because he only knew it in the Cantonese form of “阿士匹靈” (a polysyllabic loanword from English, “a+s+pr+in”). Third, certain students experienced difficulties interpreting ordinary words with non-vernacular meaning and usage, which in turn might lead to misunderstanding a science passage.

In addition to the above-mentioned perspectives and challenges, teachers and students also shared the coping strategies they used in their EMI science classrooms. These included strategic use of the L1, linking verbal meanings and other semiotic resources, strategic use of questioning techniques, employing basic strategies for learning words, and accommodating students' language ability by ignoring minor "errors".

6. Translanguaging as an Enabler of Science-Teaching Activities

As already noted, one of the key issues surrounding EMI is the role of the L1 in the classroom [55]. While the label, EMI, suggests that English is the primary means through which content should be taught, recent research highlights the affordances of multilingual meaning-making (verbal and non-verbal) in the classroom (e.g., [56]). One such increasingly valued meaning-making process is translanguaging, which initially meant "that you receive information through the medium of one language (e.g., English) and use it yourself through the medium of the other language. Before you can use that information successfully, you must have fully understood it" [57] (p. 64). Since this initial conceptualisation, translanguaging has come to encompass multiple meaning-making resources and not just verbal language (see [58]). Indeed, recent research has shown how this process of moving between multiple semiotic resources can increase the amount of dialogue, understanding, and even enjoyment in science classrooms (e.g., [50]). This has been especially true in Chinese contexts (see [59–61]).

In our study, when asked if it was appropriate to use the L1, the majority of teachers said that it was and that they used Cantonese for students with limited English ability and when referring to everyday examples for which students hear the terms only in Cantonese. For instance, one teacher stated that "if they really can't express their ideas in English, I encourage them to use Chinese, because I just want to check whether they understand" (T1); another teacher remarked, "I use Cantonese when I communicate with students with lower ability, rephrasing what the student said and trying to correct his wording in English. I provide hints and key words to students so that they can continue their answer" (T2). Some teachers also valued the L1 when it came to explaining abstract ideas or important steps in an experiment, particularly if the experiment was risky. Such strategies were indeed evidenced in the field notes from the classroom observations.

The teachers also reported that they would encourage students—especially those with limited proficiency in English—to use their L1 (Cantonese) when they found it difficult to express themselves in English. Some teachers also asked their students to translate English teacher-talk into Cantonese and provided sufficient opportunities for students to respond in Cantonese. Other teachers guided their students to respond in English through closed questions as a means to develop the students' confidence. They believed that this method reduced demand for student output and gradually encouraged them to produce phrases and short utterances in English, which they could then use to answer open-ended questions. Overall, translanguaging helped these teachers position themselves as facilitators of learning, enabling them to navigate the complexities of classroom interactions while resisting the notion that EMI lessons should be 100% in English.

The majority of students also valued the role of translanguaging in classrooms, particularly when interacting with their teachers or working with their peers during lab experiments. One student stated, "I will respond mostly in Cantonese when I need to clarify what the teacher said in English". Essentially, translanguaging helps students position themselves as coregulatory agents in collaborative activities, enabling them to interact more easily and effectively with their peers and teachers in real-time activities (see [62]). Moreover, like their teachers, the acceptance of translanguaging as part of the learning process positions students as resisting the blanket use of English in EMI lessons and once more prioritises the learning of content over language.

Overall, students and teachers recognised the added pedagogical value of translanguaging, particularly when it came to hands-on, interactive activities such as experiments. Hence, as Pun and Tai note, "a space [is] created not only for translanguaging but also by translanguaging" [50] (p. 3). Thus, we believe that instead of framing these as poor teaching/learning practices in EMI, one should recognise the importance of translanguaging.

7. Improving Analytical and Communication Skills

One key aspect in teaching is the use of effective questioning techniques, particularly when attempting to co-construct knowledge in a language besides the L1 [14,63]. For instance, it has been argued that learners not only acquire more language through interaction than monologic teacher talk [16], but that they also acquire deeper understandings of concepts [64]. Although some question this view as privileging a specific type of classroom culture (see [65]), teachers and students in our sample saw clear benefits to increased dialogue in EMI classrooms.

For instance, the teachers believed that asking the right types of questions in English is key for promoting effective science learning in EMI classrooms. One biology teacher noted that "asking the right type of question is key. I will start to teach the basic concept or content before asking the students any questions. Then, I use a range of questions at different levels, from easy to hard, to help my students consolidate their science understanding" (T1). The other teachers shared similar beliefs, stating that they too used a range of question types in English, from closed questions to higher-order questions.

The teachers also showed explicit knowledge of how the different question types can be used for specific pedagogical functions. For example, one biology teacher said that he frequently uses recall questions to remind students of what topics and content they have previously covered in his class. Other teachers said that they only used higher-order questions when the teaching topic allowed it, because students may be unable to express themselves completely in English; in other words, teachers must skilfully use higher-order questions, being aware of when they may confuse students instead of stimulating generative thoughts.

One physics teacher added that he uses lots of reasoning questions during discussions to which students can provide their answers in short English phrases. His justification for this approach is that these questions can help develop students' logical reasoning and critical thinking skills, while also not causing too much of a cognitive load in terms of using English. He added that in his teaching, he avoids focusing too much on technical terms or the English language in general but focuses more on the reasoning behind such terms. To us, this teacher seems to be incorporating a novel approach to dealing with language constraints in his classroom. Such an approach seems to open up EMI science classrooms to the adoption of techniques employed in non-EMI science classrooms. In this instance, *constellation analysis* is a way of structuring lesson plans and designs, whereby concepts can be taught and learnt by focusing on their relationships, which is not necessarily confined to verbal representations (see [28]).

In another classroom setting, one biology teacher believed that teachers should prepare students to use higher-order questions, because these require increased cognitive thinking skills. This perceived need was also noted by T1, who remarked, "I don't think students handle higher-order questions very well, since these questions require students to think deeply and apply what they have learned to a new context". We also believe this type of questioning requires students to have a good command of English in order to not only produce accurate and coherent answers, but also to understand the initial question. Hence, forcing the use of English in such situations may initially obscure the meaning of the question from some students, as their limited cognitive resources are being drawn upon to decode a relatively unfamiliar message in an L2.

Other teachers reported using a range of pre-class activities to help students develop analytical skills for learning science. One teacher said that the use of pre-lab experiment videos presented in the L2 raised students' awareness of the necessary steps for conducting experiments. He asked his students to comment on the videos and make connections with what precautions the students must consider when performing experiments. The teachers reported that this approach would motivate students to be more involved, challenge existing science concepts, and improve analytical skills regarding the understanding of an unfamiliar situation in the L2.

In order to develop better communication skills with which to express science ideas in English, the teachers also recommended strategies such as drilling exercises and dictation to help students memorise terms; some teachers also recommended the rote memorisation of facts in English, delivering the content first in English and then recapitulating it in Cantonese, and/or acting as a bilingual dictionary to translate English text—these last two items once again draw on translanguaging techniques, allowing students and teachers to integrate academic discourse with everyday discourse, link verbal language to other semiotic resources, and make strategic use of the L1 to create an interactive and enjoyable space for learning (see also [50,66]).

Overall, these teachers sought to improve students' analytical and communication skills by scaffolding, monitoring, and promoting a range of question types and strategies. Hence, such a diverse, fluid approach to EMI teaching should be recognised for its pedagogical value in helping students overcome language challenges that go beyond vocabulary, as well as highlighting how these teachers position themselves as caring individuals [44]—such a thought out and dynamic approach is clearly for the benefit of the students. Furthermore, these temporary coping and learning strategies should not be considered as obstacles to students' intellectual development, such as hindering higher-order cognitive thinking, as is often suggested [6]. Instead, they should be reframed as necessary developmental steps that teachers and students need in order to accommodate diverse language levels and rapid curriculum changes.

8. Facilitating Vocabulary Building in Science

Another key aspect to learning science (in any language) is an understanding of the technical vocabulary used in various fields. Yet, as noted already, such an understanding extends beyond ostensive, dictionary definitions and encapsulates taxonomies that represent categorical and compositional relationships, as well as how they are used in complex activity sequences (see [26]).

When asked about the vocabulary challenges in learning science through EMI, the students suggested a number of strategies that they found helpful. The first was *rote memorisation*, where students work hard on spelling, understanding the meaning in context, performing word associations, and making notes with a list of examples in complete sentences. This method helps students to develop their mental lexicon by primarily connecting the pronunciation of words (form) and their meaning (function). One student said, "In physics, chemistry and biology, there are some words that have a different meaning from the meaning we usually perceive. So, I think the solution is to spell more and do more exercises". This remark also circles back to the concerns that their teachers had above when they remarked that students do not know the alternative uses of words such as "account", "exemplify", etc.

Most of the interviewed students emphasised that memorising vocabulary meant that they truly had to understand both the English and Chinese meanings. For the students with poor English skills, knowing the Chinese meaning helped them with memorisation. Other students, however, believed that memorisation did not help them truly understand word meanings. Instead, these students suggested that they should understand how to use the word according to its context and make connections to its scientific meanings, highlighting the importance of breadth of word knowledge as well as depth of coverage for these students.

In terms of essay writing, one biology teacher suggested that, in the beginning, teachers should ignore whether students' essays are grammatically correct or not, highlighting a primacy for content over syntax in this teacher's eyes. Another biology teacher suggested that her students use a notebook to make a list of vocabulary terms to use in their essays, while another suggested utilising technology such as flipped classrooms, e-learning platforms, online bilingual materials, and text-messengers to improve the quality of teaching and to address students' language challenges. However, given the findings of recent studies, whereby EMI teachers are increasingly focusing on teaching vocabulary, and thus assuming a limited English language teaching role (see [53,55]), we find it somewhat surprising that most of the teachers in our study did not do the same. Essentially, although frequent reference was made to problems concerning vocabulary, our teachers dealt with it by guiding students toward other regulatory agents besides themselves: Namely, material artefacts (i.e., technology and textbooks) and self-regulatory processes voluntarily taken up by the students (rote memorisation, form-to-function mapping, etc.). This kind of positioning by the teachers could be due to the nature of their institution's policy documents, which do not include language as one of the core learning components; alternatively, it may simply be because they do not see themselves as teachers of discrete skills, but as facilitators of critical thinking and holistic learning in general (see also [44]).

To summarise, the teachers and students in this MOI-switching school suggested nine strategies to overcome general challenges when learning science through English. It is worth repeating that these are the coping strategies reported by the teachers and students, and not necessarily strategies that we are prescribing. Nevertheless, we reproduce some of the more novel ones below for interested readers:

- teaching questions types and question words;
- using pre-class activities to raise awareness of what will be taught in class;
- providing sample responses to similar questions types so that students know how they are expected to respond;
- embracing technology in both languages to mitigate potential and present issues regarding comprehension;
- teaching scientific terminology and concepts through constellations of meaning rather than in isolation.

9. Conclusions

This paper explored the experiences of teachers and students in EMI senior science classrooms at an MOI-switching school in Hong Kong. It detailed their views on EMI and outlined the challenges they faced and coping strategies they developed. With a small sample size from just one location, we acknowledge that generalisations cannot be drawn from our study. Nonetheless, we hope to have made a number of contributions to the burgeoning field of EMI research in science classrooms and EMI pedagogy in general.

First, the teachers we sampled strongly believed that EMI is just a tool for transmitting knowledge rather than learning a second language, which accords with other studies into EMI in similar contexts (e.g., [7,50]). Moreover, for the most part, our teachers positioned themselves as not ELTs. The students, on the other hand, considered EMI as an opportunity to improve their English while also learning science—positioning them as learners in general, who seek to develop all aspects of their knowledge base, be it content or language. This tension between content and language was reflected in both groups' desires for a school-based MOI policy that was flexible and allowed for the use of the L1 for different purposes. Nevertheless, teachers cited students' analytical, reading, and communication skills in English as major concerns, where vocabulary knowledge (primarily depth of knowledge) was seen as a major hindrance to student achievement.

Second, our findings provide additional empirical evidence of challenges related to language issues in early EMI adoption institutions. As indicated by Chan, the educational values that are offered by the fine-tuning MOI decision appear to be limited [10]. Consequently, it is questionable whether the students in MOI-switching schools, particularly students with poor English proficiency, can effectively learn in a fully English environment. Nevertheless, we believe that schools and teachers may benefit from adopting approaches to teaching science that take account of language challenges. Such approaches may not necessarily be framed in terms of L2 learners, but the complexities of scientific language in general (the authors are not prescribing ethnocentric teaching practices; see [67], for a collection of relevant studies in this respect).

Third, while many researchers have recommended eliminating the L1 from EMI science classrooms, researchers who have investigated the implications on a large scale typically argue for the benefits of L1 inclusion (e.g., [31,68]). Our findings support this view and contribute to a growing number of studies that highlight how translanguaging in EMI classrooms can promote learning by creating an interactive and enjoyable space that promotes equity in knowledge construction (see also [50,56,69]). However, in order to realise this benefit, schools and teachers must take a different stance than what has been reported in the literature regarding the implementation of EMI in Hong Kong. Namely, as Pun and Macaro note, "to allow unfettered use of the L1 is *not* going to promote quality EMI" [42] (p. 74), and thus further research is needed into how much L1 is "optimal" in this context.

Fourth, we see a need to inform EMI stakeholders on how to make language challenges more explicit and to find ways of improving coping strategies. These needs are especially true for schools switching from partial to full EMI. Moreover, we believe students in MOI-switching schools should be treated differently from students in genuine EMI schools. Specifically, we recommend that MOI-switching students be given more time to develop their confidence and improve their English proficiency before experiencing full EMI implementation. We also suggest that teachers working in MOI-switching schools undergo professional development so that they can become familiar with EMI instruction strategies and develop the necessary teaching skills to interact with students in extended verbal exchanges. We feel that this is especially important for teachers working with Grades 7 to 9, as these students are often accustomed to monologic, CMI classrooms.

With regard to limitations and future research, while we report on a single case study at a single locale, and at one point in time, the findings may be considered relevant in many other contexts around the world, as the number of students who relocate to countries where instruction is carried out in a language other than their first continues to grow at a staggering pace. Consequently, similar studies in diverse contexts are recommended to corroborate the findings and to understand the growing number of disenfranchised learners globally better. If nothing else, such studies can amplify voices that often go unheard in discussions over policy reform and best practices.

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Appendix A

Sample interview questions for teachers

- What do you think about the teaching experience in science classrooms, and the use of English as medium of instruction?
- What is your opinions about the fine-tuning policy implemented in 2010? How does it affect your daily teaching in science classes?
- What is your attitude towards EMI teaching in science?
- What is your language use in class? Do you use code-mixing? Why/why not?

- When comparing to L1 teaching, do you see any differences in your teaching styles, preparation for class?
- What language challenges, problems do you encounter in teaching science through English?
- What strategies do you adopt to handle these challenges related to English?

Interview questions for students

- What are the language challenges have you encountered in your science classrooms? What are your coping strategies when dealing with these challenges?
- Do you observe any language challenges specifically in different science disciplines? What are the coping strategies to these specific challenges?
- How do you respond to a teacher's questions or discuss among your classmates if you encounter difficulties expressing yourselves in English?
- Why types of questions does your teacher ask? How do you respond to your teacher's questions? (reluctant /quick) Do you think these questions help you to understand the key science concept introduced in that lesson? What sorts of questions are most helpful, did your teacher provide useful support for developing your understanding?
- What kind of vocabulary is essential for learning science? (technical, academic, basic)
- What are your expectations of your English proficiency in learning science?

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