# Language Challenges and Coping Strategies in English Medium Instruction (EMI) Science Classrooms: A Critical Review of Literature

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# Language Challenges and Coping Strategies in English Medium Instruction (EMI) Science Classrooms: A Critical Review of Literature

In classrooms worldwide, the use of English to teach science subjects is becoming increasingly common. There is an increasing number of English-as-a-second/foreign-language learners studying science in English. This review examines 66 empirical studies on this topic published from 2000 to 2021. We critically review and synthesise evidence of the language challenges faced by teachers and students in secondary and tertiary English medium instruction (EMI) science courses, as well as proposed coping strategies. By adopting a multidisciplinary approach, we examine our findings from three fields of research: science education, language policy and applied linguistics. Our study extends EMI research by combining language learning and canonical content learning. Our synthesis of previous findings enhances understanding of content teaching in a second/foreign language in language immersion classrooms (e.g., content and language integrated learning, content-based instruction) and provides evidence-based pedagogical suggestions for enhancing EMI science teachers' instructional practices worldwide.

Keywords: Language challenges; Coping strategies; English Medium Instruction; Science education; Critical review

## (1) Introduction

Teaching subject content in English to English-as-a-second language (ESL) or English-as-a-foreign-language (EFL) learners has become common in non-English speaking countries across the world, covering a range of educational levels and subject areas (Dearden, 2015; Macaro et al., 2018; Pun, 2019; Pun & Macaro, 2019). The use of English medium instruction (EMI) teaching can be traced back to immersion programmes developed in Canada in the 1960s (Lambert, 1981; Lambert & Tucker, 1972). Content-based instruction was then implemented in the US in the 1980s (Brinton et al., 1989; Krueger & Ryan, 1993) to help second language (L2) learners in English-speaking countries to gain language proficiency by learning subject content in English.

Research studies on teaching and learning of science in EMI setting are growing and become more diverse, since science is learnt by linguistic diverse ESL/EFL learners in countries and regions where English is an official language, such as Hong Kong, India, and Singapore. The importance of investigating EMI science classroom lies on that teaching science in English can both equip students with necessary linguistic competence and help them gain access to advanced scientific knowledge, as English is the dominant language in science communication (Ammon, 2001). Science is also taught in English in countries that do not regard English as official language (e.g., China and Japan) (Altbach, 2004; Richards & Pun, 2021). More importantly, there is a shift from the notion of EMI to Content and Language Integrated Learning (CLIL) approach, an approach that encourages teaching content and language simultaneously in science lessons (Bradley et al., 2018; Byun et al., 2011; Richards & Pun, 2022).

However, even though EMI classrooms could potentially nurture students' content knowledge and language competence (Coleman, 2006), various stakeholders such as teachers and student encountered a number of challenges. For example, some studies have suggested that EFL/ESL learners may not attain advanced English proficiency through EMI instruction (e.g., Knoch et al., 2014; Lei & Hu, 2014; Sah & Li, 2018); while another line of research studies reported that science teachers encountered difficulties to explain abstract and complex scientific concepts and thus used fewer higher-order and conceptual change questions (Pun & Thomas, 2020; Yip et al., 2003). This might be because schools and relevant authorities did not provide specific training on how teachers use EMI to teach science to second language learners (Othman & Saat, 2009; Saat & Othman, 2010). Apart from EMI science instruction being limited by students' proficiency of English language and teachers' unfamiliarity with EMI pedagogies, intrinsic motivation of less capable students is often lower compared to that of linguistically and academically more capable students (Chan, 2014). To afford the opportunities provided by EMI in science classrooms, a thorough and organized understanding of the challenges and corresponding strategies that are documented in science education literature is needed.

Notwithstanding the growing trend of EMI science education studies, there is not any critical review that synthesizes research evidence on the challenges and coping strategies of various stakeholders related to EMI science classrooms. Comprehensively examining these challenges can therefore inform students, teachers, and other EMI stakeholders about the difficulties they may encounter and the possible coping strategies they can apply. Recent reviews have provided insights into the effectiveness of EMI in promoting students' academic achievement and language improvement (e.g., Lo & Lo, 2014; Macaro, 2018; Mahboob, 2017), as well as the challenges faced (Dang et al., 2021; Ismailov et al., 2021) and potential coping strategies (e.g., Richards & Pun, 2021) in EMI classrooms. However, few studies have used a multidisciplinary approach to examine language-related issues exclusively in the context of EMI science classes or programmes. Since language is complicatedly related to culture, cognition and content (Coyle, 1999), taking a multidisciplinary view can offer deeper insights into language-related issues and the role of the English language in EMI science classrooms. We therefore critically review empirical evidence from studies in a range of disciplines: language policy, science education, applied linguistics. This enables us to improve our understanding of the main language-related challenges in EMI science classrooms and potential coping strategies, thus providing suggestions for policy makers, teachers and teacher educators. Another important aim of this critical review is to provide future research directions on the areas that is lacking in research in EMI science classroom.

## (2) Theoretical frameworks

A multidisciplinary approach is used to explore the role of language in EMI science classrooms. In this section, we foreground our critical review of literature in three disciplines: language policy, science education, and applied linguistics. The issue of teaching science in EMI settings is multidisciplinary in nature, therefore examining the issue from a single perspective can only review a facet of the tension of this issue. Adopting theoretical frameworks from each discipline can uncover the challenges and coping strategies of EMI from various perspectives.

### *Language Policy*

Language policy does not exist on its own, as it comprises "all the language practices, beliefs and management decisions of a community or polity"(Spolsky, 2004, p. 9). The framework of Spolsky (2004) is useful to analyse issues emerged from EMI science classrooms because it emphasises on the interrelations among those three components (Spolsky, 2009, 2011) and has been adopted to explore challenges faced by educators in EMI setting (Hu & Lei, 2014; Yuan & Li, 2021; Zhang, 2018). In his (2004, 2009) framework, *language belief/ ideology* refers to "what people think should be done" which is reflected by prescribed standards in curriculum documents; *language management* consists of the process of formulating a plan on language use, for example schools restricted their science teachers to use L2 throughout the entire lesson; *language practices* are how teachers and students enact behaviours and choices of language use, such as students relying on L1 during collaborative discussion in practical work (Pun & Cheung, 2021).

From Spolsky's perspective, the formidability of teaching science in EMI setting can be accounted by language ideology explicated in a country's language policy documents, since its ideology influences language management and practices. For instance, students in African countries were restricted to learn science in English fully or partially where English is their second language (Rollnick, 2000). As reviewed by Fung and Yip (2014), there is a considerable amount of evidence suggesting that using English to teach second language learners leads to a poor science academic achievement

(Heugh, 1999; Setati et al., 2002) and forms a barrier to relating science to real-life contexts (Bunyi, 1999).

The issue of EMI in science education is dynamic, complex and multidimensional. Not only do language policy and management influence language practice, language practice also drives the change of language policy and management. For example, language policy and management at school such as provision of pedagogical resources and the restriction of using L1 to write and communicate science depend on students' language competence and also impact on success of students (Sah & Li, 2018). Theoretically, EMI offers substantial opportunities to scaffold students' language competence and content knowledge (Coyle, 2007; Van Lier, 1996). However, it is important to consider dynamic and reciprocal relationships among language policy, language management and language practices, in order to shed light on the barriers of teaching science in EMI classrooms and the strategies to over these barriers.

### ***Science Education***

To examine language challenges and coping strategies in EMI science classrooms, literature commonly foregrounds the investigation in two science education theories: teacher-student questioning and teachers' knowledge (including pedagogical content knowledge and content knowledge).

Teacher–student questioning is an essential means of engaging students in cognitive activities and invoking their new language use (Coyle, 2007). Teachers can deploy appropriate questions in classrooms to help create an interactive environment for students and thus encourage them to express their ideas, which boosts students' language and content learning (Yip, 2004). Teachers' questioning techniques therefore play an important role in classroom interaction and students' conceptual construction.

Some of the reviewed studies indicated that teachers in EMI science classrooms may lack effective questioning skills (e.g., Lo & Macaro, 2012; Pun & Macaro, 2019; Yip, 2004).

An adequate grasp of content knowledge (CK) can improve teachers' questioning strategies and further enhance their pedagogical content knowledge (PCK) and teaching practices (Ward et al., 2015). Shulman (1987) noted that CK represents teachers' understanding of the subject matter they teach, and that 'PCK' refers to 'the most useful forms of representation of those ideas […] and the most useful ways of representing and formulating the subject that make it comprehensible to others' (p. 9), or knowledge of how to ensure that the subject matter is accessible. Research has shown that adequate CK enhances PCK development; if teachers are equipped with sufficient CK, they will apply strategies more skilfully to ensure that the subject knowledge is accessible to students, such as by swiftly detecting and correcting students' misconceptions (Hashweh, 1987), clearly answering students' questions and responding flexibly to unexpected events (Sanders et al., 1993) and effectively addressing students' conceptual problems (Käplyä et al., 2009).

***Applied Linguistics***

To critically examine issues arisen from EMI science classrooms, we can use various perspectives, ranging from cognitivist perspective to socio-cultural perspective to consider language and dialogue issues in knowledge construction (e.g., Mercer & Littleton, 2007). A central concept of socio-cultural theory is that mental activities such as knowledge construction and understanding are mediated by interaction with the social environment via artifacts including physical tools and semiotic resources such as language (Lantolf, 2000; Vygotsky, 1978). The competent application of these artifacts and resources is necessary when undertaking any intelligent activities (Mercer &

Littleton, 2007). Thus, language as a semiotic tool is more than just input for learners; it represents the 'resources for participation' in social interaction during knowledge development and is therefore important for content learning (Zuengler & Miller, 2006, p. 37-38).

From a cognitive perspective, Long (1996)'s Interaction Hypothesis and Swain (1995)'s Output Hypothesis can uncover how EMI science classroom provides learners with good L2 (English) learning opportunities. During EMI science instruction, teachers describe scientific knowledge in English to their students. Since scientific concepts are complex in nature, in EMI science courses, students and teachers might have many opportunities to negotiate meaning in English in specific and meaningful contexts, which could benefit students' L2 development, as explained in Long (1996) Interaction Hypothesis. During meaning negotiation, students would be asked to 'try out' their L2 knowledge to say something they are not sure (i.e., 'pushed output'), and receive corrective feedback from their peers or teachers, and ultimately have their English proficiency upgraded, as explained in Swain (1995) Output Hypothesis.

In an EMI science classroom, the application of socio-cultural theories can also reveal how students articulate knowledge and teachers mediate students' scientific thoughts. In socio-cultural theories, 'Zone of Proximal Development' (ZPD) (Vygotsky, 1978), describes the metaphorical distance between learners' actual proficiency level and the desired level that can be achieved with the assistance of a 'more knowledgeable other' (MKO) with greater proficiency in the relevant tasks, ideas and concepts. More knowledgeable others can be peers, teachers or parents. This theory suggests that teachers play a vital role in developing learners' understanding of science through language in the classroom. In authentic classroom contexts, science teachers also help ESL students to practise the use of scientific language. Within socio-cultural theories, Community of Practice (CoP) considers learning as an integral part of social practice (Lave and Wenger, 1991). They suggest that learners begin as apprentices and then are engaged in 'legitimate peripheral participation' (LPP). Their identity in practising science is formed through meaning negotiation with their seniors or teachers. They then increase their competence through interaction and practice until they ultimately become full participants in and members of the CoP in science (Wenger, 1998). The CoP perspective illustrates the importance of classroom interaction when studying science, and of understanding how the process of meaning negotiation between learners and teachers occurs. The use of language in the process of negotiating meaning is important and requires further investigation.

Integrating the perspectives of cognitive and socio-cultural theories, the language itself is an indispensable component of the content of courses instructed in a second/foreign language and has a complex association with culture, cognition and content, as suggested by Coyle (1999) '4 Cs' framework. 'Language' in this review refers to three interrelated types of language that students and teachers use and develop in CLIL/EMI classrooms, as conceptualised by Coyle (2007): language of learning, language for learning and language through learning. First, learning content via a second or foreign language, such as learning science in English in non-English speaking countries, represents the language of learning, as it enables students to access basic knowledge of various topics. This supports content learning as the content itself imposes diverse functional demands on the language used in specific situations and help students develop communicative competence (Halliday, 1973).

The promise of this critical review aims to identify language-related challenges and coping strategies in EMIs science classrooms, particularly using the lens from three fields of research, *language policy*, *science education* and *applied linguistic*s. Based on these conclusions, we address the following research questions by collecting evidence from EMI science studies and interpreting it from the theories emerged in three fields of research:

1. What language-related challenges do teachers and students encounter in secondary and tertiary EMI science classrooms?
2. What are the strategies that can be taken by different stakeholders, including policy makers, teacher educators and teachers in mitigating the language-related challenges in EMI science classrooms?

## (3) Methodology

We took a critical review approach, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021) (see Figure 1 for the PRISMA diagram). The PRIMSA has been widely accepted by the research community as evidenced by its co-publication in many journals, and citation in more than 60,000 reports (Page et al., 2021). Our international focus enabled us to identify how science is taught in English to ESL/EFL learners worldwide, yielding insights for the international community into relevant theories and practices in EMI science classrooms.

[Insert Figure 1]

We first identified specific topics from the literature review, i.e., language-related challenges and coping strategies in EMI science classrooms. Next, in line with Macaro (2019), we followed four steps to systematically select and review relevant studies: (1) literature identification; (2) literature screening and extraction; and (3) result analysis. As our aim was to provide a multidisciplinary and systematic review of EMI science issues, our research team consists of an author who is an academic in science education and an experienced science teacher and two authors who are academics in applied linguistics. As this critical review features the nuances of EMI in teaching science content subjects, we argue that the issues of EMI in science classrooms are owned by both content and language specialists (Macaro and Aizawa, 2022). Therefore, as evidenced in the team of this critical review, the development of EMI research in science education needs to be appropriated by linguists and non-linguists.

***1) Literature identification.***

To identify relevant literature for screening, we developed our first two sets of key words by taking references from previous EMI systematic reviews (e.g., Graham et al., 2018; Lo & Lo, 2014), which were (1) 'language', 'linguistic', 'second language', 'L2', 'ESL', 'EFL', 'English-medium', 'English medium instruction (EMI)' and 'medium of instruction (MOI)'; and (2) 'science', 'chemistry', 'physics', 'biology', 'science education', 'teaching', 'instruction', 'teacher', 'curriculum' and 'syllabus'. However, the research team added another set of key words which would fit the research purposes of the current review, including 'challenges' and 'coping strategies'.

Journals and online databases were then identified. We identified appropriate journals in two stages. In the first stage, two authors, one from science education background (content specialist) and another from applied linguistics background (language specialist), shortlisted 20 journals each according to their research expertise as they are familiar with journals of their field. Of these 40 journals, 26 were agreed upon by the team. As the review focused on ESL/ EFL learners of science in EMI classrooms, journals devoted to specific subfields of science teaching in L1 classrooms or with populations including English native speakers were excluded. This limited the scope of the review. In the second stage, an additional list was drawn up by manually checking the references of relevant reviews. After further discussion, 32 journals were finally agreed upon by the team. These were *Language and Education, Linguistics and*

*Education, RELC Journal, International Journal of Bilingual Education and Bilingualism, Bilingual Research Journal, Journal of Immersion and Content-Based Language Education, The Language Learning Journal, Journal of English for Academic Purposes, English for Specific Purposes, Language Teaching, ELT Journal, TESOL Quarterly, Language Teaching Research, Journal of Multilingual and Multicultural Development, Asia Pacific Journal of Education, American Educational Research Journal, Harvard Educational Review, South African Journal of Education, The Asia-Pacific Education Researcher, Higher Education, Higher Education Quarterly, International Journal of Instruction, Current Issues in Language Planning, International Journal of Science Education, Journal of Science Education and Technology, Journal of Research in Science Teaching, BMC Medical Education, International Journal of Science and Mathematics Education, EURASIA Journal of Mathematics, Science and Technology Education, System, Sustainability* and *PLoS ONE*.

We then searched online linguistics, education, science, and psychology databases, considering the interdisciplinary nature of EMI and the complexity surrounding its labelling and definition. We obtained articles for review from the following databases: the Education Resources Information Centre (ERIC) for education; Language and Linguistics Behaviour Abstracts (LLBA) for linguistics; and PsycINFO for psychology. For science, we searched the Web of Science (Social Sciences Citation Index: 1956–present; Conference Proceedings Citation Index – Social Science & Humanities: 1990–present; Book Citation Index – Social Sciences & Humanities: 2005–present). We searched ProQuest Dissertations and Theses (global full text plus UK and Ireland abstracts) to access doctoral dissertations relevant to the current review.

Third, we conducted an advanced search using the string (language OR linguistic OR ‘second language’ OR L2 OR ESL OR EFL OR ‘medium of instruction’ OR MOI OR English-medium OR EMI OR English Medium Instruction) AND (‘science education’ OR science OR chemistry OR biology OR physics OR teaching OR instruction OR teacher OR curriculum OR syllabus) in the TITLE search entry, and (challenge) AND (‘coping strategies’) for the ABSTRACT search entry. Only research reports which were published from 2000 to 2021 and written in English were considered for inclusion in the review. The rationale for searching literature with publication date after 2000 was that there was a drastic increase in the number of research studies on EMI (Macaro, 2018). In our view, the drastic surge implies advancement of EMI teaching and research, as well as curriculum development around various countries.

Finally, we manually checked the reference lists of the initially surveyed articles to identify any key journal articles or doctoral dissertations that could also be included. In this round, 3303 studies were identified from advanced search in five online databases mentioned above. 861 duplicates and 99 conference proceedings were removed, leaving 2343 studies for subsequent screening and extraction.

***2) Literature screening and extraction.***

We conducted these two tasks, literature screening and extraction, simultaneously, and performed an initial screening before our in-depth screening.

In the initial screening, we read the titles and scanned the abstracts of the initially selected articles and then independently excluded entries if they met one of the following conditions: (1) the studies were not written in English; (2) the studies were not related to EMI and (3) the studies were not related to science education. After the initial screening, 2149 entries were removed, leaving 194 studies for the in-depth screening.

During the initial screening stage, we also considered whether the search terms needed to be refined. Following discussion, we reached a consensus on the studies to be removed and the search terms to be used. In the in-depth screening stage, we scanned the full texts of 194 studies and excluded ~~an~~ additional 128 articles for failing to meet the inclusion and exclusion criteria: (1) empirical data were reported; (2) the subject(s) learned by some or all of the participating students was (were) among the natural sciences (e.g., chemistry, biology, physics) or otherwise science-related (e.g., biomedical science programmes); (3) the instructional language was English; (4) students whose first language was not English made up the majority of the participants; (5) the focus was secondary or tertiary education. Studies were excluded if (1) none of the investigated subjects were in the natural sciences or otherwise science-related; (2) they did not specifically report on students' learning or teachers' teaching in natural science or other relevant subjects; (3) they performed document analysis of policy research; (4) they were systematic reviews, meta-analyses, or commentaries; (5) they were not peer reviewed; and/or (6) they were Master's dissertations (as these were not sufficiently peer-reviewed).

We finally selected 66 articles for quality assessment. We entered their details, such as their objectives, contexts (nation/region, educational level and investigated subjects), research design, participant characteristics and key findings (challenges and strategies), into an Excel spreadsheet.

***3) Result analysis.***

Through in-depth reading of 66 studies, we synthesised evidence of the language challenges experienced by teachers and students in EMI science classrooms and proposed coping strategies. The findings are presented below in three broad research areas, with several subthemes for each.

## (4) Findings

### *An Overview of Selected Studies*

From a multidisciplinary perspective, this critical review synthesises the identified language-related challenges students and teachers encounter in EMI science classrooms and the corresponding coping strategies from 66 empirical studies published from 2000 to 2021. The articles we reviewed focus on EMI science education at secondary and tertiary levels. Of these, 63.6% were conducted in secondary EMI science classrooms and the remaining 36.4% in tertiary education, such as bachelor's degrees or master's programmes (Table 1). The geographical scope of the reviewed articles covers Asia (71.21%), Africa (9.09%), Europe (9.09%), the Middle East (4.55%) and North America (0.66%) (Table 2). We found that Hong Kong science EMI courses receive most of the research attention, and 40.91% of the investigated empirical studies are situated in Hong Kong schools, and particularly in secondary schools. In terms of research designs, most of the studies (42.42%) took a qualitative approach, using data from diverse sources such as classroom observations, interviews, and surveys. More details of the research design distribution are given in Table 3.

[Insert Table 1]

[Insert Table 2]

[Insert Table 3]

We found that language-related challenges and coping strategies in EMI science classrooms were explored in three main areas: science education, language policy and applied linguistics (see Figure 2, for the mind map of themes and sub-themes).

[Insert Figure 2]

***A. Language Policy***

*1. Language-related challenges*

As revealed in Spolsky (2004)'s framework, language *belief/ideology*, language *management* and language *practices* are dynamically correlated and are critical components of language policy. Therefore, the reviewers took the lens of the interrelationship of these three components to identify language-related challenges in language policy. A review of six studies indicates that there might be a mismatch between macro-level English-only ideology and micro-level teachers' and students' language beliefs and language practices (Pun, 2021; Pun et al., 2022; Rahman & Singh, 2021; Tan, 2011), and some potentially problematic issues related to language might emerge in EMI policy implementation (Chan, 2014; Yessenbekova, 2022).

Start with Rahman and Singh (2021) research on students' and teachers' language-related ideologies in Bangladesh tertiary STEM courses. Even though English was required by the policymaker as the only instructional language in Bangladesh tertiary education, teachers and students highly welcomed the inclusion of multilingual resources as a support to students' comprehension of science knowledge, and translanguaging through English and Bangla has been a predominant micro-level language practice. The macro-micro mismatch was also be seen in Malaysian (Tan, 2011) and Hong Kong secondary EMI science classrooms (Pun, 2021; Pun & Thomas, 2020) where students' English improvement was assumed to be one of the pedagogical goals by policy makers. However, science teachers might believe that they were not responsible for language teaching or dealing with language difficulties, which could probably be caused by the time and pressure from high-stakes assessment (Tan, 2011). In addition, there might be an underemphasis of catering students' and teachers' language readiness for EMI science classrooms in EMI policy implementation.

Yessenbekova (2022) case study, for example, by interviewing teachers and students in undergraduate EMI science classrooms at a Kazakhstani university, revealed that the university's language management system might need improvement since administrators neglected the need to address students' language-related challenges. Students even without eligible English proficiency could be enrolled in EMI programmes by passing lenient English proficiency selection criteria, and it could reflect that the university did not cautiously consider students' language capability to handle EMI science and neglected students' language needs in the school-level EMI policy implementation. Similar situation could be seen in the Turkish university (Ekoç, 2020). In a similar vein, qualitative results from Chan's (2014) research showed that when carrying out EMI policy in the former L1 MOI school (CMI), teachers' readiness to accommodate students' language ability might be given insufficient concern. Teachers though equipped with high English proficiency did not necessarily teach science in English effectively to students since they taught in 'university English' rather than in the way that students could comprehend the content.

This mismatch between macro-level English-only language ideology and micro-level students' and teachers' multilingual language beliefs and language practices could to some extent reflects the controversy between policy makers' expectations and realistic situations in EMI science teaching, and further requires a reconsideration of language ideology, management, and practices in EMI policy. When EMI policy is implemented at the school level, language-related challenges, such as students' insufficient English proficiency and teachers' unreadiness to teach science in simpler English, have been constantly neglected in previous practices.

*2. Suggested strategies to policy makers*

To tackle language-related challenges of implementing EMI policy in science classrooms, previous studies have tried to explore solutions from the aspects of language beliefs, management and practices. A predominant suggestion identified from the review is to introduce a multilingual perspective into language ideology (Andersson & Rusanganwa, 2011; Pun & Thomas, 2020; Pun et al., 2022; Rahman & Singh, 2021), management (Chan, 2014; Fung & Yip, 2014; Pun et al., 2022) and practices (Andersson & Rusanganwa, 2011; Pun & Tai, 2021; Pun & Thomas, 2020) in EMI science classroom.

To be more specific, policy makers might need to acknowledge that students' and teachers' diverse linguistic resources could play a beneficial role in meaning-making and knowledge-construction since their bi-/multilingual competence provides spaces for teaching and learning, such as official instructional space where English is only used, and personal space where students' L1 could be used for improving interaction and scaffolding (Andersson & Rusanganwa, 2011). As mentioned previously, there was a mismatch between macro-level English monolingual ideology and micro-level students' and teachers' multilingual beliefs and translanguaging practices in EMI science classrooms, which reflects the need of shifting to a more inclusive and flexible language policy to fit the actual EMI science teaching situations (Rahman & Singh, 2021; Yessenbekova, 2022). Moreover, it is advocated that policy makers could pay more attention to students' learning process and outcome than sets of declarative statements of language policy (Pun & Thomas, 2020) .

Meanwhile, it might need much cautiousness in the flexible use of students' multiple linguistic resources, for example their L1, because the 'unfettered use of the L1 is not going to promote quality EMI' (Pun & Macaro, 2019, p. 74) and may reduce students' opportunities for learning academic English through rich descriptions of specific ideas with contextual information (An et al., 2019; Pun & Macaro, 2019). Scholars such as Pun et al. (2022), Chan (2014), as well as Fung and Yip (2014) proposed 'school-based' or 'classroom-based' view when teachers manage students' L1 use in EMI science course. Teachers might consider students' previous EMI experience, science knowledge and linguistic difficulties when planning for L1 use in the classroom. Specifically, for students who switched from L1 MOI learning to EMI learning, they need more linguistic support. These linguistic supports include teachers' advocation of more L1 use, and their provision of time to build up students' confidence (Pun et al., 2022). Students with relatively poor capacity in science learning might find it more challenging when studying science in English, their L2, so a higher proportion of home language instruction with vocabulary given in English could be helpful for their comprehension. For high-ability students, L1 use could only play a supplementary role to EMI instruction. (Fung & Yip, 2014). On the other hand, language difficulties faced by students during EMI science classrooms, which include scientific terminology, scientific sentence structure and grammar, could provide references for teachers on where L1 might be used (Chan, 2014). An understanding of what type of linguistic challenges students face might help teachers adapt their instruction and help student overcome the barriers of linguistic challenges in learning canonical science content.

To activate students' and teachers' multilingual resources in EMI science classrooms, strategies such as code-switching and translanguaging could be helpful tools (Andersson & Rusanganwa, 2011; Pun, 2021; Pun & Tai, 2021; Pun & Thomas, 2020). For instance, teachers could give students manuals for practical work in English but allow students to use their L1 in discussion with peers. A flexibility in enforcing the medium of instruction policy by teachers could ensure students' enough exposure to English and at the same time engage students in meaningful discussion with L1 as a semantic resource. Researchers such as Fung (2020), Yessenbekova (2022), as well as Rahman and Singh (2021) proposed a professional development initiative for increasing teachers' translanguaging awareness in EMI science classrooms, which could help them to recognise the opportunities of exploiting multilingual resources.

## ***B. Science education***

### *1. Language-related challenges*

From the perspective of science education, two language-related challenges were identified in the empirical studies, a lack of high-order questioning and limited opportunities for teachers to develop their PCK of Content and Language Integrated Learning.

In guided inquiry, often high-order questioning is needed to think about the design of practical work and sense-making of the collected results. Three of the reviewed studies revealed that teachers often consider the linguistic demands of high-order questioning (Pun & Macaro, 2019; Yip, 2004; Yip & Cheung, 2004). In EMI science classrooms, different types of questionings inherited various pedagogical functions: a) checking students' understanding of information and their ability to explain a science phenomenon (lower order); b) evaluating students' higher cognitive skills, such as evaluation, synthesis, and analysis (higher order); c) investigating their learning motivation (motivation); and d) encouraging conceptual changes in students' scientific knowledge (conceptual change) (Yip & Cheung, 2004). Under the consideration of students' forming complex thematic patterns, students might not be answered questions that challenge their thinking. As a result, they were not often provided mental challenges that could scaffold their investigative skills and critical thinking skills.

Analysis of the literature identified that EMI science courses and teachers lack both the instructional strategies and pedagogical support (e.g., teaching materials) which in turn presents language challenges for the teachers and students in EMI science classrooms. Firstly, teachers have limited opportunities to develop their PCK in CLIL. The study by David and Venuste (2021) reported that CLIL was not incorporated as a formal agenda in school science curriculum. Owing to this reason, teachers did not recognise that subject-specific language practices, such as scaffolding students' learning of classification system, was an important learning objective. Apart from a lack of school curricula objective, Yip and Cheung (2004) highlighted that instructional materials for practical work were prescriptive in nature. Students might have a few chances to develop their linguistic resources while engaging in disciplinary practices, namely identifying daily-life problems, formulating hypothesis, designing investigation and evaluating evidence (Yip & Ho, 2003). Secondly, as highlighted by Fung and Yip (2014), ~~was that~~ instructional materials did not provide sufficient opportunities to bridge students' L1 and L2 linguistic resources. Often these instructional materials (e.g., textbooks) provided a L1 glossary, underemphasising that a L1 everyday word could correspond to multiple English every day and scientific terms. Coupled with a lack of CLIL instructional materials and curriculum objectives, three of our reviewed studies pointed out there was a lack of professional development programs for EMI teachers (Kim, Kweon, et al., 2021; Sahan et al., 2021).

*2. Suggested strategies to teachers*

Regarding the language-related challenges identified from the perspective of questioning and PCK, we also identified proposed strategies in these reviewed studies. To overcome language barriers in questioning, teachers could consider students' vocabulary depth and breadth, as well as students' challenges in translating complex taxonomic relationships learnt in mother language into EMI (Pun et al., 2022). Teachers and policy makers could also consider the use of bilingual approach into questioning students in inquiry-based EMI science classrooms (David and Venuste, 2021). For example, teachers could use L1 high-order question helped students break down complex concepts into simpler concepts, as well as challenging students to think about relationships between component parts, for example, identifying the structure-behaviour-function relationships of biological self-explanations (Pun & Macaro, 2019).

Empirical studies in our review have also outlined four suggestions that could be incorporated in professional development programs for CLIL in science classrooms (An & Thomas, 2021; Pun et al., 2022): (1) developing teachers' capacity to orchestrate dialogic science classrooms; (2) providing exemplary teaching materials; (3) supporting whole-school approach for EMI science classrooms; (4) offering individualised professional development programs for science teachers. Firstly, a study began to characterise strategies in improving input modification strategies (e.g., simplified vocab and paraphrasing) to deliver complex scientific ideas (An and Thomas, 2021). This could help students to refine their use of scientific language and gain accuracy in describing science processes so students are more willing to ask questions and express their ideas (Pun et al., 2022). Secondly, the teaching materials can adopt a thematic-pattern-based concept + language mapping (CLM) approach which encourages CLIL through understanding semantic patterns within various science disciplines (He & Lin, 2019). Thirdly, researchers and the government could provide school-level support for EMI schools, for example, making teachers aware of the nature of scientific discourse (Lo, 2014), and promoting collaboration among teachers of different subjects in how to systematically use L1 to engage students in scientific discourse (Sahan et al., 2021). Fourthly, as different teachers have various needs in promoting students' CLIL, universities and the government could provide individualizing PD programmes according to teachers' needs and actual situations, such as teachers' availability, mode preference (Kim, Kweon, et al, 2021), the profile of schools and students (Sahan et al, 2021), teaching experience, gender, age and language proficiency (Cañado, 2020). These four important suggestions, as identified in our review, could shed light on future professional development models in CLIL for engaging multilingual learners in disciplinary practices in science classrooms.

### *C. Applied Linguistics*

#### *1. Language-related challenges*

Although there are increasing number of EMI science classrooms focusing CLIL, students' motivation to learn English is limited by their lower language proficiency. Students with limited English proficiency encountered various academic language-related challenges, in both productive and receptive tasks (Soruç et al., 2021), such as challenges in reading science texts, understanding complex sentences with various pronouns and subordinate clauses and discussing with peers due to limited fluency, accuracy and vocabulary (e.g., Bolton et al., 2017; Lu et al., 2021). They are more likely to demonstrate unsatisfactory academic performance than other students. Such cases could be seen in many EFL/ESL contexts, such as United Arab Emirates (Schoepp, 2018), mainland China (An & Thomas, 2021) and Hong Kong (Yip et al., 2007). Results in Schoepp (2018)'s research indicated that university students with entrance IELTS exam score of 5.0 were at an academic disadvantage and demonstrated poorer performance than those with score of 6.0/6.5/7.0 in all subjects (such as science and maths). Moreover, limited English proficiency could impede students' willingness to ask teachers questions and their comprehension of teachers' instruction (An & Thomas,

2021) as well as students' fluent expression (Yip et al., 2007) which could discourage teachers from using interactive approaches during instruction.

More importantly, science language itself could impose challenges to learners as it involves specialised lexico-grammatical features, and a wide scope of technical vocabulary which is carefully used to express abstract concepts, logical relationships, and universal phenomena (Halliday & Martin, 1993). Its discourse patterns include interlocking definitions, lexical density, nominalisation, and grammatical metaphors (Halliday & Webster, 2006). The non-technical terms used in science English may also have unique contextual meanings and should therefore be differentiated from their use in day-to-day contexts (Lewis et al., 2011). Students could find it difficult to accurately phrase questions about science in English which by nature demands high-level precision and accuracy (An & Thomas, 2021). Understanding specialized scientific terms of a wide range is another typical challenge for English language learners (ELLs) in EMI science classrooms (Evans & Morrison, 2011; Lee et al., 2020; Yip & Tsang, 2007; Yip et al., 2003). In addition, the textbooks used in EMI science courses might be monologic and highly demanding ~~of~~ for students, in terms of 'packing' information from decontextualised content and specialised technical terms (Pun, 2019).

Apart from lexico-grammatical features, teacher-centredness has been identified in the EMI science classrooms of both English non-native speaker teachers (NNSTs) (Lo, 2014; Lo & Macaro, 2012; Yang et al., 2019; Yip & Cheung, 2004; Yip & Tsang, 2007) and native speaker teachers (NSTs) (An et al., 2021). For example, Lo (2014) found a significant lower proportion of student talk with shorter turns and fewer Initiation-Response-Feedback (I-R-F) sequences in Hong Kong EMI science classrooms compared with humanities ones. Interactive activities such as asking students questions and group discussions were not frequently observed in EMI science classrooms (Yip &

Cheung, 2004; Yip & Tsang, 2007). The teacher-centredness was still obvious in NSTs' classroom even though a potential factor for teacher dominance, teachers' limited English proficiency, was removed (An et al., 2021). Teacher-dominated instructional practices do not only reduce the teacher-student interactions required for developing necessary scientific inquiry skills (Wellington & Osborne, 2001), but also inhibit students' natural L2 development.

*2. Suggested strategies for stakeholders*

To address challenges caused by English proficiency, stakeholders might consider providing language support to teachers and students before and during EMI science courses.

To better prepare students and teachers for new EMI courses, stakeholders can consider implementation of or improvements in bridging programmes, EAP/ESP courses for students and language training for teachers. Bridging courses can offer a buffer period to incoming students who may not be used to disciplinary-specific terms in English, despite their previous exposure to EMI or their English proficiency (Pun & Jin, 2021). Students may also focus on improving their English skills before embarking on EMI courses to prepare them for L2 science learning (Marsh et al., 2000, 2002). For the bridging course design, Kim, Park and Baldwin ~~and colleagues~~ (2021) proposed a new Integrated Content and Language in Higher Education (ICLHE) course which was designed within Coyle's 4Cs conceptual framework (Coyle, 2017), consisting of pre-activities and post-activities related to content, along with classes collaboratively designed by language teachers and content professors. Although the effects of this introductory ICLHE course on students' content knowledge improvement were not examined, students thought the course was helpful for their future EMI content learning. When designing English for Academic Purposes (EAP) and English for Specific

Purposes (ESP) courses, stakeholders could take students' EMI experience (Evans & Morrison, 2011) and students' need for more subject-specific terms and examples into consideration (Pun & Jin, 2021). Evans and Morrison (2011) suggest that generic EAP courses are more suitable for students without previous EMI learning experience, and discipline-specific EAP can meet the needs of those accustomed to learning content in English, as their substantial active and passive vocabulary can help them tackle more specialised courses.

More language-related supports are required for science learning in EMI classrooms, including multilingual resources (e.g., the use of L1), non-linguistic strategies, pedagogical language strategies and vocabulary exercises. The use of L1 by students and L1 techniques such as code-switching and translanguaging can support EMI instruction and are advocated by many researchers (e.g., Fung, 2020; Othman & Saat, 2009; Probyn, 2001; Pun, 2021; Pun & Tai, 2021; Swanson et al., 2014). However, the casual use of L1 may reduce students' L2 learning opportunities (Pun & Macaro, 2019), and the 'optimal' level of L1 is yet to be identified (Pun et al., 2022). For a strategical use, L1 could be employed to (1) explain basic or key concepts on which they can build their subsequent understanding (Sukardi & Sopandi, 2021) and scientific concepts that are too complicated for students to comprehend via English (Othman & Saat, 2009); (2) help students catch up when they become lost or have difficulties in phrasing questions quickly (An & Macaro, 2022); (3) assist students to develop and communicate scientific arguments (Swanson et al., 2014) and (4) help new EMI students make a smooth transition (Lo & Macaro, 2012). Teachers should also consider students' vocabulary levels when assessing the time and the extent to which L1 should be used, because students should know at least 95% of the lexical items in a text to understand its meaning (Hsueh-Chao & Nation, 2000). They may otherwise have to resort to additional strategies to compensate (Macaro, 2021). An awareness of students' lexical knowledge can inform how L1 can be deployed as a support for EMI instruction. A glossary of both general academic vocabulary and subject-specific terms may also help enhance students' comprehension (An et al., 2019; An & Thomas, 2021). The difficulties in understanding teachers' L2 instruction, which result from limited linguistic knowledge, can be eased by considering the previous knowledge of students in EMI learner strategies (Macaro, 2021), as this can enable them to understand the overall meaning without attending to each word. This previous knowledge can be used by teachers as a bridge to the taught content when preparing lessons (Dong, 2002; Seah & Silver, 2020).

Other studies (e.g., Byun et al., 2011; Evnitskaya & Morton, 2011; Ferreira, 2011; Pun, 2019) take this notion further, suggesting that subject teachers should be aware of and cater to students' English needs in addition to the vocabulary issues previously discussed. Strategies for externalising such language awareness can be obtained from the actual teaching practices of experienced EMI teachers, such as on-the-spot assessments to evaluate students' abilities to use topic-relevant language, and purposely integrating student discussions with corrective feedback into instruction, which can prompt students to notice the appropriateness of their language use (Seah & Silver, 2020). Collaboration with language experts can help identify the potential language challenges students may encounter during science EMI classes, thus enabling subject teachers to better understand students' language needs (Poon et al., 2013; Pun & Thomas, 2020). Similarly, students can work with language tutors who are familiar with content knowledge in the L2 used in upcoming lessons, and thus identify potentially problematic vocabulary. However, as ~~(Pun & Thomas, 2020)~~ Pun and Thomas (2020) suggested, this strategy may be more suitable for an 'idealised EMI classroom' in which students' English proficiency has reached the threshold required for instruction. Collaborations between subject lecturers and language teachers can be extended to the whole teaching cycle, which is referred to as team teaching (Lasagabaster, 2018). Some studies (e.g., Meskill & Oliveira, 2019; Xu & Zhang, 2022) have indicated that team teaching can effectively improve teachers' sensitivity to students' language difficulties and requirements during class and raise their awareness of their roles as not only best owners of subject knowledge but also language facilitators. Moreover, co-teaching with language teachers can help subject teachers improve their language skills and confidence (Xu & Zhang, 2022).

Non-linguistic accommodation strategies vary across contexts, but they focus on making the content knowledge taught via English more comprehensible and therefore acceptable to students. They include using body language and visuals, speaking slowly when encountering complex ideas and drawing on practical examples from students' daily lives (Probyn, 2001; Soruç et al., 2021). David and Venuste (2021) proposed a set of pedagogical language strategies for improving Tanzanian secondary students' performance in biology EMI courses. These include (1) using language supportive activities; (2) translating when necessary; (3) interpreting for students; (4) working with students on their pronunciation; (5) using language genres specific to the subject and the topics; (6) using a glossary; and (7) applying simple English sentences. Empirical results show a significant improvement in students' academic performance in biology after the intervention. Such strategies can be applied to students' L2 science learning, but more research confirming their generalisability to the field is required. Some of the methods discussed above, such as translation and simplification, should be used carefully (Tan, 2011).

Activities proposed to encourage peer interaction in EMI classes include assigning group tasks, requesting students to provide summaries of previous lessons, arranging presentations and journal clubs and other active reading tasks (Dong, 2002; Rowland & Murray, 2019; Sahan et al., 2021; Yip & Cheung, 2004). Supporting multimedia resources can also enhance students' active interactions (Lo & Macaro, 2015). To better prepare teachers for EMI instruction, training should not only focus on lecturers' language proficiency improvement but also the development of their interaction strategies. They can then scaffold students to offer lengthier outputs with more sophisticated linguistic structures and therefore help them to move the conversations forward together with teachers (An et al., 2021). Teachers should consider students' needs to encourage student-centredness during EMI science classes. Science EMI courses can include students with diverse levels of English proficiency (Probyn, 2001) and cultural backgrounds (Byun et al., 2011), and thus ~~it is necessary to understand what and thus~~ appropriate teaching strategies should be identified to encourage student participation. Lin (2006) examined interactions in successful bilingual science classes in the 1980s, which encouraged high cognitive gains and conceptual changes in students. She concluded that these classes offered practical bilingual pedagogies by drawing on the students' available linguistic resources, such as a rich L1 semantic context, code-mixing strategies and specific Initiation-Response-Feedback (IRF) patterns in the L1 followed by a recap in the L2. Lin proposed that such bilingual pedagogy can help students with lower English proficiency develop linguistic competence so they can access scientific discourse in English. Teachers should be more aware of students' cultural-based understandings of the interaction process, such as their familiarity with the participation modes expected in EMI science classrooms and the interactional patterns common in other science courses. Based on these, teachers can attempt to connect to their home cultures in class (Quinn et al., 2012). Various types of vocabulary, including technical terms and general academic vocabulary, may also influence students' comprehension of teachers' instruction. Teachers should therefore be aware of language forms when teaching content knowledge (An et al., 2019) and of students' diverse L2 needs in science learning (Ferreira, 2011).

## (5) Discussion

In this critical review, we took a multidisciplinary approach to synthesise research evidence from the three research areas, namely science education, language policy and applied linguistics. In the first part of this section, we elaborate how these three areas of research provide comprehensive insights and suggestions on the issue of teaching science in the context of EMI. Following the discussion of the suggestions to different stakeholders, we also highlight future research implications in examining the language-related challenges and coping strategies in EMI science classrooms in each area of research.

### *Language policy: The role of policy makers in aligning macro- and micro-level practices*

Considering the role of L1 in EMI science classrooms, policy makers can change their language ideology from only allowing the use of L2 to a flexible use of both L1 and L2 by teachers and students. Our review of literature has indicated that a multilingual perspective in policy enactment matches with the linguistic reality in science classrooms (Andersson & Rusanganwa, 2011; Pun & Thomas, 2020; Pun et al., 2022; Rahman & Singh, 2021; Yessenbekova, 2022). We would argue that an inclusion of multilingual perspective in government's language ideology could facilitate a better language management and language practices. Empirical research findings already indicate the importance of L1 in helping low-ability students to master scientific language (Fung & Yip, 2014). This new perspective would not discourage school leaders, teachers and students to use L1 which can help them learn thematic patterns in scientific language (Pun and Cheung, 2021).

Another important suggestion is that curriculum documents could increase their emphasis on using other modes of representation in EMI science classrooms in their "language" ideology. Many scholars have raised several notions underpinning micro language practices in EMI science classrooms, such as translanguaging (Pun & Tai, 2021). Language ideology needs to reorient their focus from a set of declarative statements to the learning processes and outcomes (Pun and Thomas, 2020). In the authentic learning processes of using L2 to learn science, it often involves different modalities (Cheung and Winterbottom, 2021a, 2021b) and students' whole-body sense-making (Pun, 2021). For example, in practical work sessions, students often integrate tactile, visual, symbolic and linguistic modes of representation (Pun and Cheung, 2021; Pun and Tai, 2021). To make these agendas explicit, the curriculum documents can incorporate notions such as translanguaging.

***Science education: limited opportunities for science teachers to develop pedagogical content knowledge for content and language integrated learning***

Despite the importance of questioning and teachers' pedagogical content knowledge in practising CLIL learning in science classrooms, our review studies indicate that there are limited opportunities for teachers to develop disciplinary-specific knowledge and skills. From the themes identified through the lens of science education (Table 4), some skills of questioning and pedagogical content knowledge in CLIL are specific to science classrooms. For example, research studies have reported that questioning in EMI science classrooms could provide mental challenges in guided inquiry (Yip and Cheung, 2004; Pun and Macaro, 2019). This could facilitate students' development of skills of scientific investigation and data analysis. Another example is that a L1 every day term can correspond to L2 scientific terms in different parts of speech (Fung and Yip, 2014). Teachers often recognise and bridge the correspondence between L1 and L2 everyday and scientific terms. Though these sets of skills and PCK are specific to science CLIL, these arguments in our included studies were often slightly buried in the finding section and were not explicitly highlighted in the discussion section. It is apparent that there is a lack of empirical studies on how teachers develop such skills and knowledge with professional development programmes tailored for the purpose of CLIL.

As these sets of skills and PCK could be specific to science as a discipline, future research studies could design professional development models that improve science teachers' skills and knowledge in CLIL. In our review, we highlighted several coping strategies catering for developing teachers' questioning and PCK in CLIL. For questioning, teachers could use bilingual approach in asking high-order questions and consider taxonomic relationships among scientific terminologies; for PCK in CLIL, we identified developing teachers' instructional strategies in creating dialogic science classrooms, provision of exemplary teaching materials and framework for content and language integrated learning, as well as institution-level and individualised support for EMI science teacher. These coping strategies can inform the development of a potential professional development model for CLIL in science education.

***Applied linguistics: continuous language supports to both teachers and students***

EMI science classrooms in previous studies (e.g., An et al., 2021; Lo & Macaro, 2012; Tan, 2011) were identified as teacher-dominated with little teacher-student interaction which however is a key component for students' language development from interaction hypothesis (Long, 1990) and their identity construction before becoming full participants in and the members of the CoP in science (Wenger, 1998). Language-related challenges faced by teachers and students, such as students' under-threshold English proficiency (e.g. Schoepp, 2018; Soruç et al., 2021), teachers' inadequate ~~of~~ concern in students' language needs (e.g., Block, 2021; Block & Moncada-Comas, 2019; David & Venuste, 2021) and distinctive linguistic features of science English (e.g., An & Thomas, 2021; Evans & Morrison, 2011; Saat & Othman, 2010) might account for didactic EMI science classrooms. For instance, students with limited English proficiency could find it challenging to read, talk about, listen to, and write science-related materials in class or ask teachers questions in English which demand high-level precision and accuracy (An & Thomas, 2021), so the student-teacher interaction might be decreased. Teachers' challenges in delivering subject knowledge in a clear and acceptable manner in English could negatively influence teachers' role as a 'MKO' to students, who should scaffold students during their science learning.

As language-related challenges could influence the classroom interaction which is important for students' science knowledge construction and language development, the stakeholders could consider provide continuous and diverse language support for teachers and students before and during EMI science courses (e.g., Kim et al., 2017; Kim, Park, et al., 2021; Margić & Vodopija-Krstanović, 2018). Bridging courses and EAP/ESP courses could be helpful to prepare students linguistically eligible and help them become familiarized with subject-specific terms before embarking on EMI courses. Moreover, the individualized view could be employed when considering the design of these preparatory programmes. Students' individual characterises for example, their EMI learning experience (Evans & Morrison, 2011) could be the criteria for programme design. During EMI science classrooms, teachers might need to be aware of students' language difficulties and needs, and provide scaffolding via L1 techniques (e.g., translanguaging and code-switching) (e.g., Fung, 2020; Pun & Tai, 2021; Swanson et al., 2014), pedagogical language strategies (e.g., using language supportive activities) (David & Venuste, 2021) and non-linguistic accommodation strategies (e.g., using body language and speaking more slowly) (Probyn, 2001; Soruç et al., 2021). Continuous language development programme for science teachers and a collaboration with language experts/teachers could help teachers to predict or identify students' language-related challenges and then teachers could provide necessary scaffolding.

### Limitation of this study

This review has its limitations. More than half of the reviewed articles are within the Hong Kong context, which is understandable as Hong Kong was a British colony and the English language culture is deep-rooted. The introduction of a 'fine-tuning' MOI policy in Hong Kong in 2010 also encouraged the use of English as the medium for teaching subject content. Future reviews can examine the use of EMI in science learning across a broader geographical scope. Our focus is on EMI science studies in secondary and tertiary education, and so other educational phases can be also considered in future, such as those in primary schools. Future review can also compare how EMI in science instruction is discussed in empirical and theoretical studies (see an example from Cheung and Erduran (2022)).

## (6) Conclusion

Using English as the medium of instruction for teaching subject content has been a common pedagogical practice in non-English speaking countries (Dearden, 2015; Macaro et al., 2018; Pun & Macaro, 2019) as EMI can enhance students' English proficiency via learning CK (Coleman, 2006). English is the lingua franca that offers access to international communities of business, technology and science. However, the implementation of EMI courses faces various challenges, including language issues. Language plays a crucial role in knowledge construction, communication and therefore content learning, and its importance is theoretically grounded by sociocultural and sociolinguistic theories, the CoP theory and SLA principles. Research (Othman & Saat, 2009; Pun & Macaro, 2019; Williams, 2015; Yip et al., 2003) has indicated that EMI may not necessarily enhance students' content learning, due to language-related problems such as teachers' and students' language proficiency and teachers' lack of knowledge of how to teach subject knowledge in English. This critical review identifies the empirical evidence on language-related challenges teachers and students face in EMI courses. In addition, we identified coping strategies that were either proposed to tackle specific language challenges or that had been adopted in actual pedagogical practices. The review scope was narrowed down to EMI science courses to provide a more specific view.

A multidisciplinary approach was taken in this paper, and therefore the findings can offer various stakeholders a comprehensive assessment of language issues in EMI science courses. The studies reviewed cover both secondary and tertiary education, and this critical review offers relevant stakeholders such as teachers, students, policy makers and faculties insights into the language-related problems teachers and students encounter, their needs in EMI science classes and suggestions for teacher training programmes, student development courses and EMI science classroom improvement. The findings are relevant to researchers in the fields of educational linguistics and science education. The identified challenges and coping strategies in this review can inform science teachers worldwide about evidence-based pedagogical practices used to enhance L2/FL science students' learning outcomes and methods addressing science students' L2/FL issues. In addition, this review provides combined evidence related to content teaching through second/foreign languages in various language immersion classrooms (e.g., content and language integrated learning, content-based instruction).

**Declaration of interest statement**

The authors report there are no competing interests to declare.

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Table 1. Distribution of empirical studies by education level

| *Educational Level* | *No.* | *%* |
|---|---|---|
| ***Secondary*** | 42 | 63.6% |
| ***Tertiary*** | 24 | 36.4% |

Table 2. Distribution of empirical studies by country/region

| *Geographical region* | *Country/Region* | *No.* | *%* |
|---|---|---|---|
| ***Asia*** | Mainland China | 7 | 10.61% |
| | Hong Kong | 27 | 40.91% |
| | Korea | 4 | 6.06% |
| | Malaysia | 3 | 4.55% |
| | Indonesia | 1 | 1.52% |
| | Bangladesh | 1 | 1.52% |
| | Kazakhstan | 1 | 1.52% |
| | United Arab Emirates (UAE) | 1 | 1.52% |
| | Singapore | 2 | 3.03% |
| | **TOTAL** | **47** | 71.21% |
| ***Africa*** | South Africa | 3 | 4.55% |
| | Tanzania | 1 | 1.52% |
| | Botswana | 1 | 1.52% |
| | Rwanda | 1 | 1.52% |
| | **TOTAL** | **6** | 9.09% |
| ***Europe*** | Italy | 1 | 1.52% |
| | Spain | 4 | 6.06% |
| | Croatia | 1 | 1.52% |
| | **TOTAL** | **6** | 9.09% |
| ***Middle East*** | Turkey | 3 | 4.55% |
| ***North America*** | US | 4 | 6.06% |

Table 3. Distribution of empirical studies by education level and research design

| **Education Level** | **QUAN** | **QUAL** | **Mix-method** | **Total** |
|---|---|---|---|---|
| **Secondary** | 6 | 18 | 18 | 42 |
| **Tertiary** | 7 | 10 | 7 | 24 |
| **Total** | 13 | 28 | 25 | 66 |
| **%** | 19.70% | 42.42% | 37.88% | 100% |

Table 4. Summary of reviewed studies categorized by themes

| **Language policy _Challenges** | | |
|---|---|---|
| Language ideology | Policy maker:<br>A mismatch between macro-level EN-only ideology and micro-level stakeholders' positive ideologies towards translanguaging | Rahman and Singh (2021) |
| | Teacher: | Pun (2021) |

| | | |
|---|---|---|
| | the weak language awareness of teachers in late partial EMI schools | Pun & Thomas (2020)<br>Tan (2011) |
| Language management | Potentially problematic implementation of EMI policy | Ekoç (2020)<br>Yessenbekova (2022) |
| Language practices | Neglect of students' linguistic difficulties when implementing EMI policy | Chan (2014) |
| **Language policy _Coping strategies** | | |
| Language ideology | Dealing with a mismatch between macro-level language ideology and micro-level language practices | Rahman and Singh (2021)<br>Yessenbekova (2022) |
| | Multilingual perspective in EMI science classroom | Andersson and Rusanganwa (2011)<br>Fung (2020)<br>Pun and Thomas (2020)<br>Pun et al. (2022)<br>Rahman and Singh (2021)<br>Yessenbekova (2022) |
| Language management | Catering to students' language difficulties in EMI science courses when implementing EMI policy in school- and classroom-level | Chan (2014)<br>Pun et al. (2022) |
| | Flexible school-based EMI policy based on students' English proficiency and previous learning experience (MOI) | Pun et al. (2022)<br>Yip et al. (2007) |
| | Flexible classroom-based MOI based on students' science knowledge level | Fung and Yip (2014) |
| Language practices | Exploiting students' full linguistic repertoire via translanguaging strategies or code-switching in EMI science courses | Andersson and Rusanganwa (2011)<br>Pun and Thomas (2020)<br>Pun and Tai (2021)<br>Pun (2021) |
| **Science education _Challenges** | | |
| Questioning | Insufficient use of high-order questions in EMI science classrooms | Pun and Macaro (2019)<br>Yip and Cheung (2004);<br>Yip (2004) |
| Limited opportunities for developing teachers' PCK in CLIL | T's confusion in identifying subject- and language- specific objectives during lesson plan | David and Venuste (2021) |
| | Lack of appropriate instructional materials | Fung and Yip (2014)<br>Othman and Saat (2009)<br>Yip and Cheung (2004) |
| | Insufficient EMI-related teacher professional development (PD) programmes | Kim, Kweon, et al. (2021)<br>Pun (2021)<br>Sahan et al. (2021) |
| **Science education _Coping strategies** | | |
| Questioning | Bilingual approach in asking questions in EMI science classroom | David and Venuste (2021)<br>Pun and Macaro (2019) |

| | | |
|---|---|---|
| | Considering students' confusion with asking high-order questions | Pun et al. (2022) |
| Strategies for developing teachers' PCK in CLIL | Developing T's instructional strategies in creating more 'dialogic' science classroom | An and Thomas (2021)<br>Pun et al. (2022) |
| | Provision of exemplary teaching materials and framework for content and language integrated learning | David and Venuste (2021)<br>He and Lin (2019)<br>Yip, Coyle & Tsang (2007) |
| | Institution-level support for EMI science teacher | Chan (2014)<br>He and Lin (2019)<br>Lo (2014)<br>Pun et al. (2022)<br>Sahan et al. (2021)<br>Yip, Coyle & Tsang (2007) |
| | Individualised PD programme design | Cañado (2020)<br>Chan (2014)<br>Hoare (2003)<br>Kim, Kweon, et al. (2021)<br>Pun et al. (2022)<br>Sahan et al. (2021) |
| **Applied linguistics _Challenges** | | |
| Teachers' and students' English proficiency and language requirements in EMI science classrooms | Ss' limited English proficiency correlated with unsatisfactory academic performance and scant interaction | An and Thomas (2021)<br>Bolton et al. (2017)<br>Lo and Macaro (2012)<br>Lu et al. (2021)<br>Pun (2022)<br>Schoepp (2018)<br>Soruç et al. (2021)<br>Yip and Cheung (2004)<br>Yip et al. (2007) |
| | Distinctive features of "Science English" adding more workload on students | An and Thomas (2021)<br>Evans and Morrison (2011)<br>Lee et al. (2020)<br>Pun (2019)<br>Pun et al. (2022)<br>Saat and Othman (2010)<br>Yip et al. (2003)<br>Yip and Tsang (2007) |

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|---|---|---|
| Teacher-Student interaction in EMI science classrooms | Teacher-centred science EMI classrooms | An et al. (2021)<br>Chan (2014)<br>Lo (2014)<br>Lo and Macaro (2012)<br>Tan (2011)<br>Yang et al. (2019)<br>Yip and Cheung (2004)<br>Yip et al. (2007)<br>Yip (2003) |
| **Applied linguistics _Coping strategies** | | |
| Suggestions for dealing with English proficiency issues | Continuous English learning programmes for teachers and students before EMI science class (e.g., bridging courses, EAP/ESP courses, teacher language development programme) | Cañado (2020)<br>Evans and Morrison (2011)<br>Kim, Park, et al. (2021)<br>Kim et al. (2017)<br>Marsh et al. (2000)<br>Marsh et al. (2002)<br>Margić and Vodopija-Krstanović (2018)<br>Pun and Jin (2021) |
| | Language-related support during EMI science courses (e.g., L1 use, science teacher-language teacher collaboration, pedagogical language strategies, non-linguistic accommodation strategies) | An et al. (2019)<br>An and Macaro (2022)<br>An and Thomas (2021)<br>Byun et al. (2011)<br>Evnitskaya and Morton (2011)<br>David and Venuste (2021)<br>Dong (2002)<br>Ferreira (2011)<br>Fung (2020)<br>Lin (2006); Othman and Saat (2009)<br>Poon et al. (2013)<br>Pun (2019)<br>Pun (2021)<br>Pun and Thomas (2020)<br>Pun and Tai (2021)<br>Pun et al. (2022)<br>Probyn (2001, 2006)<br>Probyn (2001)<br>Prophet and Badede (2009)<br>Rowland and Murray (2019)<br>Seah and Silver (2020)<br>Soruç et al. (2021)<br>Sukardi and Sopandi (2021)<br>Swanson et al. (2014)<br>Tan (2011)<br>Xu and Zhang (2022)<br>Yip (2003) |

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|---|---|---|
| Suggestions for teacher-student interaction in EMI science classrooms | Increasing student-centred activities and attention to language forms | An et al. (2019)<br>An et al. (2021)<br>Dong (2002)<br>Ferreira (2011)<br>Lin Lin (2006)<br>Lo and Macaro (2012)<br>Lo and Macaro (2015)<br>Rowland and Murray (2019)<br>Sahan et al. (2021)<br>Yip and Cheung (2004) |

Figure 1. PRISMA flow diagram of research protocol (adapted from Page et al, 2021)

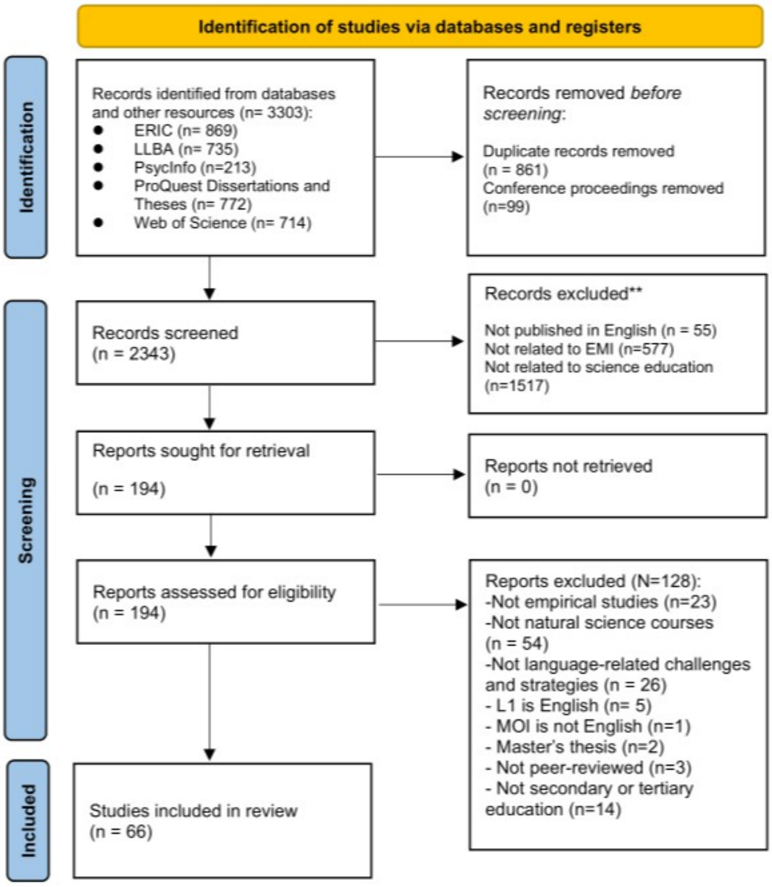
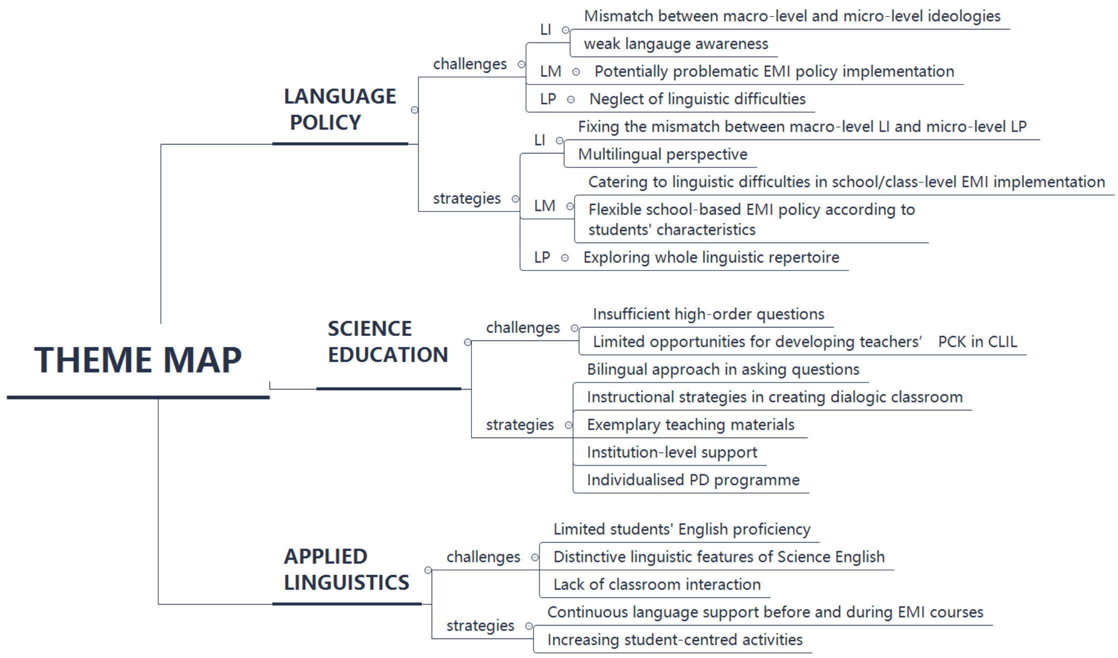


Figure 2. Mind map of themes and sub-themes




**Notes**: LI: language ideology, LM: language management; LP: language practice