A review of a decade of scaffolding practices for learning in CLIL science classrooms

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This systematic review examines scaffolding practices in science instruction within Content and Language Integrated Learning (CLIL) environments, where English as a foreign language is the medium of instruction (L2). Adopting PRISMA guidelines, 1,052 records were identified, of which 19 were eligible for inclusion. Our analysis shows the essentiality of rediscursification (modifying instructional discourse) and transsemiotization (combining semiotic resources to enhance the message). It also shows variability in the discourse around translanguaging (the fluid use of languages) across contexts, and that preferences for scaffolding practices are shaped by cultural dispositions. The majority of the studies were non-experimental and focused on vocabulary, with only a minority applying heuristics designed for integrating content and language. We raise the question whether some multimodal resources and students' first languages truly promote science literacy in CLIL. Finally, we provide research-based implications for science CLIL teachers and trainers to support deeper learning in the L2 science classroom.

Keywords: content and language integrated learning (CLIL), science, scaffolding, rediscursification, translanguaging, transsemiotizing, cultural dimensions.

1. Introduction

Our purpose in this study was to explore scaffolding practices that are considered conducive to learning in the science classroom where the language of instruction is English as a foreign language. Motivated by the multilingual and socioeconomic needs of the European Union, language policies in Europe have propelled the shift from teaching English as a language subject only to adopting it as the medium of instruction in non-language content subjects (the Council of the European Union, 1995). To address the difficulty of allocating more hours for foreign languages as curricular subjects in compulsory education and to improve students' language levels, Content and Language Integrated Learning (CLIL) was devised in the mid-1990s as a novel teaching approach. This educational approach implies the use of a selected additional language, often English (Lasagabaster & Sierra, 2009), for communicating subject-specific content, and thereby the alternation of the communicative focus between content and language-form and the use of supportive methods when teaching (Coyle, Hood & Marsh, 2010, p. 3). As interest surges in the integration of content and language, CLIL research is increasingly concentrating on classroom interactions and pedagogical practices that cultivate subject-specific literacies, notably where CLIL is positioned within content classes, moving beyond assessments of attitudinal changes and outcomes of academic achievement (Dalton-Puffer, Hüttner & Llinares, 2022).

Among the curricular subjects taught through English in content-driven CLIL programs are the Natural Sciences, such as Biology, Chemistry, Physics, and Geology. These subjects represent complex bodies of knowledge. One challenging aspect is the technical and semantically dense nature of scientific language (Lemke, 1990, p. 139), which can be difficult even in the students' first language. Students may easily confuse terms and concepts that carry both common-sense, everyday meanings as well as technical scientific meanings (e.g., light and heat), leading to misunderstandings of entire concepts, examples, and equations (Lemke, 1990, pp. 35-39).

Another even more challenging aspect of Science texts is their intricate thematic patterns, comprising thematic items (concepts and processes) that are connected through semantic relationships (Lemke, 1990, p. 12). For instance, 'evaporation', 'condensation', and 'precipitation' are connected by cause-and-effect relationships. These patterns can either be condensed into broader terms, such as 'water states,' or extend into a 'thematic nexus'—a network of interrelated concepts. Such multi-layered complexity makes science both linguistically and cognitively demanding. Moreover, where English is foreign language (EFL or L2) and the language of instruction, accessing academic knowledge becomes a thorny issue for teachers and a persistent challenge for students, who are developing both language proficiency and academic literacies (Nikula et al., 2016). The construal of knowledge and the development of subject-specific literacy in science through the L2 thus require socialization into its highly intertextual nature using multilingual, multimodal resources (Duff, 2010, p. 169; Swain & Lapkin, 2013), for which scaffolding is indispensable (Mahan, 2020). This is especially pertinent as CLIL programs are intensifying their focus on cultivating subject-specific literacies, employing theory-based interventions and pedagogical practices that bridge content and language learning (Dalton-Puffer et al., 2022), primarily through scaffolding techniques.

Against this backdrop, a review of studies on scaffolding practices in science classrooms is invaluable for identifying best practices and potential gaps when navigating the language of science. Therefore, this review serves to inventory the assessed and reported scaffolding practices identified in existing literature, focusing specifically on classroom interactions, one of three key CLIL domains alongside curriculum and learning outcomes, and participant perceptions (Dalton-Puffer et al., 2022).

2. Scaffolding in CLIL and Science

Scaffolding is a pivotal teaching practice grounded in sociocultural learning theories, influenced by the works of Wood, Bruner, & Ross (1976) and Vygotsky (1978). It manifests as both spontaneous actions and as carefully planned processes that teachers employ to guide students beyond their individual capabilities, through quality dialogue, as well as by leveraging additional visual and tactile experiences (Vygotsky, 1962, p. 26).

The significance of scaffolding is especially critical where the cognitive load of learning is amplified by instruction in a foreign language, which requires more strategic planning to balance cognitive and linguistic demands (Cummins 1984). Scaffolding is thus integral in CLIL. It adopts Second Language Acquisition practices, such as recasts and rephrases, as observed by Llinares et al. (2012), to improve the accuracy and preciseness of students' utterances (Ellis & Sheen, 2006). It also includes practices based on cognitive load management theories for regulating the mental effort in working memory (Cooper, 1998), including visual modifications of texts and task breakdown and sequencing, as seen in Coyle et al. (2010, pp. 87-109) and Ball, Kelly & Clegg, (2015).

At this juncture, it is important to highlight that the primary focus of scaffolding in content-driven CLIL contexts is on the subject content and its associated language, such as the specific language of science, rather than foreign language learning per se (Coyle et al., 2010). In other words, scaffolding aimed away from the target subject and its specific linguistic demands requires a rationale.

In the context of science instruction, the importance of multimodal resources alongside quality verbal interaction has been emphasized as key for scaffolding learners (Lo & Lin, 2019; Williams & Tang, 2020; Piacentini, 2021). To tackle the inherent challenges of science learning (Lemke, 1990), Polias (2016) provides guidelines that advocate for including various media (including PowerPoint, written text, and videos) and multiple forms of meaning-making (including visual, auditory, textual, and physical resources). They encompass a range of strategies: moving from concrete to abstract concepts, highlighting subject-specific vocabulary, transitioning from everyday language to a more academic register, recycling fundamental principles and their relevant language patterns, sequencing activities, and engaging students with questions that are both achievable but that can also deepen their understanding. These guidelines largely fall under the category of planned or designed scaffolds, but Polias (2016) asserts that teachers must also be attentive to moments during classroom interactions when spontaneous shifts between content and language are required.

Different stages of science learning call for certain scaffolding techniques. Some are more related to guiding input for decoding information and building schemata, centering on language and concepts at the word level (e.g., reading and labeling a diagram), the sentence level (e.g., drawing on text, spoken or written, to sequence sentences), and the whole text level (e.g., extracting information from a reading into a table and concept mapping). Others are more typical for aiding learners to process information and guide their production of target thematic patterns (e.g., sentence starters, information gaps, gap fills, substitution tables, and more) (see Ball et al., 2015; Coyle et al., 2010).

2.1 Leveraging L2 discourse

Fundamentally, scaffolding in CLIL is expected to meet the demands of the conceptual content and the language that accompanies it, as opposed to centering on language-teaching pedagogy by itself (see Coyle et al., 2010, p. 86).

In relation to scaffolding input and information processing, Lorenzo (2008) posits that complex academic topics in English as an L2 can be made accessible without compromising their integrity or accuracy through what he labels ‘simplification’, ‘elaboration’, and ‘rediscursification’ of content. ‘Simplification’ in his framework refers to lowering linguistic complexity by reducing the number of words per sentence and using more frequent vocabulary. ‘Elaboration’ refers to exemplifying, paraphrasing, and providing repetitions to enhance meaning, thereby lengthening discourse.

Lastly, ‘rediscursification’ refers to teachers’ adaptations of texts to heighten the learners’ interaction with the content. In this process, the original discourse is subject to transformations resulting from introducing pre-tasks and questions; rearranging content; suppressing some parts; and recomposing the materials. These changes help introduce more engagement devices, highlight information, and make abstract concepts more concrete.

This emphasis on moving from abstract to concrete understanding resonates with the notion of discourse variation as outlined by Llinares et al. (2012). They illustrate how dialogic exchanges in science lessons often begin with common-sense everyday language engaging students in the target scientific topic and subsequently transition to a more scientific and authoritative discourse, constituting the ‘official version’ or scientific story, marked by scientific and dense terms. Importantly, these types of discourse are complementary to one another, and varying them allows scientific talk to move across time in semantic waves between different levels of context-dependence (semantic gravity) and complexity (semantic density). The intertwining of various discourse types serves to mediate the depth and complexity of the scientific discourse, making it more accessible to learners.

While Lorenzo’s (2008) three forms of input modification were originally intended for scaffolding written texts, they can be applied to understand classroom interaction as well. Spoken discourse is more dynamic, allowing for the co-occurrence of simplification and elaboration, both subsumed within rediscursification. To clarify, when engaging students in a new topic, teachers may combine ‘simplification’ and ‘elaboration’ by offering synonyms as well as giving examples. Such actions often form part of a larger ‘rediscursified’ dialogue, where the teacher also asks questions to prompt thought, recall, and comprehension checks. In this way, simplification and elaboration are subsumed within the broader strategy of rediscursification during oral discourse'.

2.2 Leveraging multisemiotic resources

More recently, translanguaging and transsemiotizing have emerged in alignment with the shift towards multilingualism and multiliteracies in 21st-century CLIL (May, 2014), reflecting the multi-semiotic nature of contemporary teaching-learning environments.

Translanguaging is not merely the flexible use of multiple languages; its underpinnings extend beyond observable practices. Earlier conceptualizations of translanguaging saw it as a pedagogical practice for alternating local and target languages to support minority languages and scaffold content comprehension until the weaker language had developed (Duibhir & Cummins, 2012; Cenoz & Gorter, 2021). Outside of minority language contexts, translanguaging represents the fluid use of multiple linguistic resources, contrasting with monolingual or rigid multilingual norms (Lemke & Lin, 2022). This expansive communicative repertoire allows for nuanced expressions and deeper understandings that single language systems may limit. Lemke and Lin also extend this flexibility to the epistemological domain, positing that it enables a pluralism in knowledge forms; thus, the students' first language (L1) serves as an additional cultural and cognitive resource in classroom settings.

This view aligns with García's (2009) emphasis on the plurilingual nature of learners, which allows them to negotiate meaning in more than one language, including translation and providing multiple pathways for cognitive engagement, thereby facilitating a deeper understanding of complex concepts (Lemke & Lin, 2022).

Transsemiotizing involves the use of non-verbal paralinguistic resources in conjunction with verbal messages, including visuals, graphics (images, animation, graphs, sketches), prosody (pitch movement, volume, speed of delivery, stress, and stretching) as well as gestures and physical movements (e.g., Wu & Lin, 2019). Transsemiotizing seeks to enhance verbal messages by integrating non-verbal paralinguistic resources, yet emergent bilinguals may use the latter to substitute second language utterances (Williams, 2022). Thus, assessing the effectiveness of meaning making resources in CLIL settings should consider whether these resources have a merely compensatory function or contribute to enhancing the comprehension of content matter.

2.3 Factoring 'culture' into scaffolding practices

To fully grasp the nuances of scaffolding science instruction in CLIL settings, it is crucial to acknowledge that teaching is profoundly shaped by cultural influences. While it may be tempting to think of science teachers sharing a uniform culture, teachers rarely do (Feiman-Nemser & Floden, 1986) given their different belief systems (Woods, 1996), the environments in which they teach—including the schools themselves and the varied cohorts of students they engage with, modifying their views on the best approaches to aid student learning.

In this regard, Flowerdew and Miller (1995) presented a framework of four cultural dimensions drawn from the analysis of longitudinal ethnographic data in contexts where English, the medium of instruction, is not the students' first language. Flowerdew and Miller (1995) put forward that social-psychological traits based on ethnicity influence student and teacher behaviors. In East Asian countries, such as China, South Korea, and Singapore, Confucian teachings promote respect for teachers, being regarded as the primary knowers and role models (Also see Tu, 1996). This respect fosters caution when sharing opinions or asking questions. Students are reported to be careful with their speech as they wish to be certain before responding.

Confucianism also motivates high achievement, hence students' centredness on academic success, which is measured in test achievement. Social-psychological traits vary in the West. In Finland, for example, repeating a school year is not viewed negatively as education aims to prepare individuals for adult life, not mainly for exams (Suwalska, 2018). This results in valuing direct instructions on what to learn versus independent information seeking and original thinking. In their attempt to distinguish between both, we found Flowerdew and Miller's 1995 discussions around ethnic culture to center on the beliefs and values underlying achievement, whereas discussions of academic culture center on teachers' approaches and styles. Their discussions of local culture pertain to the familiar aspects of the local environment, showing, for example, in expected communication conventions. As for disciplinary culture, it concerns how the content of a discipline influences the modes of communication and interaction.

3. The objectives of the study

While Polias' (2016) volume offers a comprehensive guide to optimal scaffolding practices in CLIL science classrooms, our goal is to investigate the scaffolding techniques that are actually employed in real-world classrooms, as substantiated by empirical studies. Regarding previously published comprehensive volumes and reviews on teaching and scaffolding science in CLIL settings, these have primarily focused on either the Asian context, as seen in Lo and Lin (2019)—specifically Hong Kong, Mainland China, and Singapore—or the European context, as discussed in Piacentini (2021), which centers on the underpinnings of CLIL and language-related practices beneficial to science education. Others, like Williams and Tang (2020), have emphasized non-linguistic and tactile modes of meaning-making. Our contribution in this study is to bridge existing gaps by focusing on all studies that positively conveyed and appraised scaffolding practices for science instruction in CLIL.

We include research from both Asian and European contexts that identify as content-driven CLIL settings and encompass both linguistic and non-linguistic forms of scaffolding. We focus on examining scaffolding practices specific to CLIL settings where both teachers and students share a first language but use English for instruction. Given that the regulation and research interests in CLIL education differ by country, we believe these aspects would be even more varied when compared to other forms of content-based language education.

Therefore, the aim of this review is to present a comprehensive synthesis of the scaffolding practices (linguistic and non-linguistic) observed in CLIL science classrooms that are deemed effective, according to the authors of the original studies, for facilitating learning science through English. In relation to the latter, three questions were posed:

RQ1: What is the range and characteristics of the studies that target scaffolding practices for learning in the CLIL science classroom?

RQ2: What forms of scaffolding were observed in the practices of CLIL science teachers in these studies?

RQ3: What cultural or contextual influences emerge in these studies, if any?

4. Methodology

4.1. Databases and Search strategy

Both EBSCO and SCOPUS databases were used to mine the studies published on the topic between 2010 and 2022. The keywords and Boolean searches used were “Content and Language Integrated Learning” OR “CLIL” AND “Science”, in the titles and abstracts of peer-reviewed journals. The flow chart below (Figure 1) shows the search, filtering, and analysis process following the guidelines of ‘Preferred Reporting

Items for Systematic reviews and Meta-Analyses'—PRISMA (Moher et al., 2009). The search returned a total of 1052 articles (809 in EBSCO and 243 in SCOPUS). After excluding the duplicate records, 939 remained, the abstracts of which were screened using 7 inclusion keywords: science; natural science(s); biology; chemistry; physics; environmental science(s), and geology. Full articles were then assessed for eligibility in the remaining 131 records by applying the inclusion-exclusion criteria.

The inclusion criteria were directed at empirical studies published in English that: showcased classroom scaffolding practices (e.g., teacher/student interaction, written and spoken discourse/texts) in primary and secondary stages; were content-driven; featured visible linguistic practices for science instruction; had English as the language of instruction; and targeted settings where the extracurricular linguistic environment was *not* English.

The exclusion criteria filtered out studies that were concerned with affective issues (motivation, perceptions, attitudes, ideologies); focused on scores and academic achievement; piloted 'CLIL' for only a limited number of hours/classes/weeks (e.g., short-term CLIL projects); did not include the natural sciences (e.g., social sciences); evaluated CLIL solely as an approach; targeted EFL (English as a foreign language); targeted teacher education and training; and finally, were not published in peer-reviewed journal articles.

The process resulted in excluding another 112 records, leaving 19 records to be analyzed for scaffolding practices.

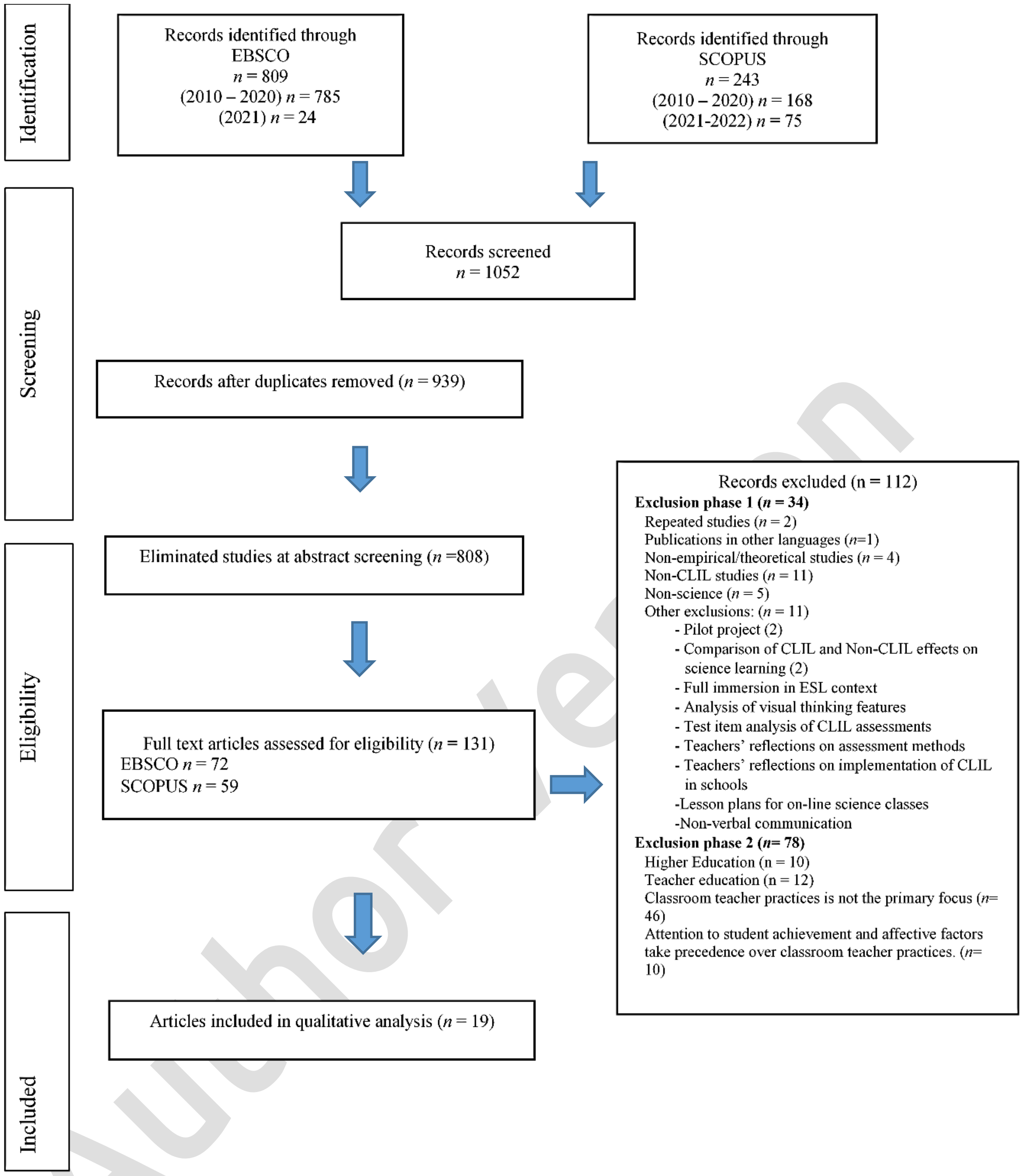

Figure 1. Flowchart of search, inclusion, and exclusion screenings, following PRISMA 2009 (Moher et al. 2009)

4.2. Analysis of the studies

Given the diverse methodologies, objectives, and classroom settings in the studies we reviewed, established scaffolding frameworks were not directly applicable in our case. Their specificity limited their utility for capturing the range of scaffolding practices we encountered. Hence, we developed a customized coding scheme to enable a more nuanced analysis. Thematic analysis was applied for a more in-depth analysis of the 19 studies in this qualitative study. Codes were generated inductively drawing on the reviewed frameworks and constructs, discussed in the literature review (see section 2). Following Braun and Clarke (2012), these codes were refined as needed and renamed as we progressed in the analysis of the forms of scaffolding in the included studies.

The codes generated for scaffolding discourse were:

(1) Rediscursification: It involves simplifying input, enhancing input (e.g., emphasizing prosody in oral talk and highlighting lexical units in written text), and elaborating on input, using different questioning techniques, as well as varying horizontal and vertical discourse to engage students and scaffold their learning. (Lorenzo, 2008; Llinares et al. 2012)

(2) Translanguaging: It entails multilingual practices. Teachers accept and make use of the learners' multilingual repertoires, including code-switching and translating (Lemke & Lin, 2022; García, 2009; Otheguy et al., 2015) to facilitate interaction and comprehension.

(3) Transsemiotizing: It entails shifts between linguistic and non-linguistic multimodal resources (visuals, media, gestures, bodily movement…etc.), whether to scaffold the comprehension of instructional talk (Chen et al., 2022; Wu & Lin, 2019) or to push the students to pay attention to specific patterns and process these prior to written production.

(4) Contexts and Cultures: It refers to Ethnic, academic, local, and disciplinary dispositions that influence the scaffolding practices and how these are perceived in the target studies.

Based on Flowerdew and Miller's (1995) cultural dimensions in relation to the scaffolding practices *Ethnic culture* in this study will refer to traditional and societal norms that shape students' reactions to certain scaffolding practices. These norms may prioritize certain forms of knowledge over others. *Academic culture* here will refer to ways of knowing, encompassing the teaching styles, techniques, and perceptions of effective teaching and scaffolding unique to a specific science-CLIL setting. *Local culture* in scaffolding will be seen through the linguistic preferences and communication conventions observed in classroom exchanges. More specifically, the use of the mother tongue, and its role. Also, the use of culturally relevant examples to facilitate the explanation of scientific concepts further. Finally, *disciplinary culture* refers to the specific practices to support the different branches of science teaching, seen in the selection of different aids for scaffolding science in English.

5. Results

5.1. The range and characteristics of the target studies

Table 1 is a view of the range and the attributes of the final studies that were included for their focus on scaffolding (n=19), classified by author, country, participants' age range, the subjects in which the studies were conducted, and the research methods applied.

Table 1. The final included studies targeting scaffolding in English-CLIL science classrooms [*=(Quasi) Experimental studies)]

Author	Country	Students' ages	Subject(s)	Data-analysis method(s)	Focus of the study
Kang, Hwang, Nam & Choi, (2010)	South Korea	8 to 9	Science (& Maths)	Quantitative	Compares NNES/NES practices to see whether CLIL may forfeit students' content learning at the expense of L2 learning.
Evnitskaya & Morton (2011)	Spain	12 and 16	Biology	Qualitative	Explores teacher-student interactions.
Escobar-Urmeneta & Evnitskaya (2014)	Spain	12	Biology	Qualitative	Explores teacher-led discussions (academic/technical terms).
Nikula (2015)	Finland	13	Physics and chemistry.	Qualitative	Explores interactions during hands-on activities for subject-specific language use.
Morton (2015)	Spain	13 and 16	Biology (&Technology)	Qualitative	Analyses teachers' vocabulary explanations (general academic words).
Kääntä, Kasper & Piirainen-Marsh (2018)	Finland	13	Physics	Qualitative	Analyses teachers' vocabulary definitions and explanations (subject-specific terms).
Mahan, Brevik & Ødegaard (2018)	Norway	14 to15	Science (&Mathematics + English)	Qualitative	Explores the characteristics of discourse in science and maths lessons (vs. English language lessons).
Fernández-Barrera (2019)	Spain	12	Science (& Maths)	Qualitative	Explores the transformation of pedagogical practices.
He & Lin (2019)	China	15 to 16	Biology	Mixed Methods	*Explores interactions during Concept + Language Mapping" (CLM) approach to determine its effectiveness.

Ho, Wong & Rappa (2019)	Singapore	16 to 17	Biology	Qualitative	*Explores interactions when using concept sketches and language mapping prior to writing and their effect.
Lo, Lui & Wong (2019)	China	13 and 14	Science	Quantitative	Examines instructional practices for scaffolding and assessment purposes.
Wu & Lin (2019)	China	15	Biology	Qualitative	*Explores instructional practices when employing the Multimodalities-Entextualisation cycle.
Lo, Lin & Liu (2020)	China	12 to 13 15 to 16	Biology & Chemistry	Qualitative	Analyses teachers' discussions of scientific concepts.
Tsang (2020)	China	15 to 17	Chemistry	Mixed Methods	*Explores the benefits of employing the Multimodalities-Entextualisation cycle.
Mahan (2020)	Norway	15 to 16	Natural Science (& Social Sciences)	Qualitative	Explores forms of scaffolding for content comprehension and task completion in science.
Pinho Feller (2021)	Portugal	8 to 9	Natural sciences	Qualitative	Explores translanguaging as a pedagogical tool.
Tagnin & Ní Ríordáin (2021)	Germany (2 schools) & Italy (1 school)	15 to 17	Biology	Mixed Methods	Explores instructional practices with focus on questions.
Gómez Ramos, Palazón Fernández, Lirio Castro & Gómez-Barreto (2022)	Spain	9 to 11	Natural sciences	Quantitative	*Explores the effect of using graphic organisers on students' ability to recognise lexical categories (parts of speech)
Roca de Larios, Coyle & García (2022)	Spain	9 to 10	Science (a topic in Physics)	Mixed Methods	*Explores the effect of a CDF/SFL-based intervention on students' writing

The majority of studies targeted secondary students aged 12-17 (84%). Most of the studies were qualitative (63%), followed by mixed methods (21%) and quantitative approaches (16%). Studies incorporating specific interventions for scaffolding interventions made up approximately one-third of the total (31%) (see Table 1). As shown in figures 2 & 3, the included studies came mostly from Europe, specifically Spain (32%), followed by Asia, mostly China (25%). Individual subjects were the primary focus (68%), with Biology being the most common (32% alone, 10% with other subjects).

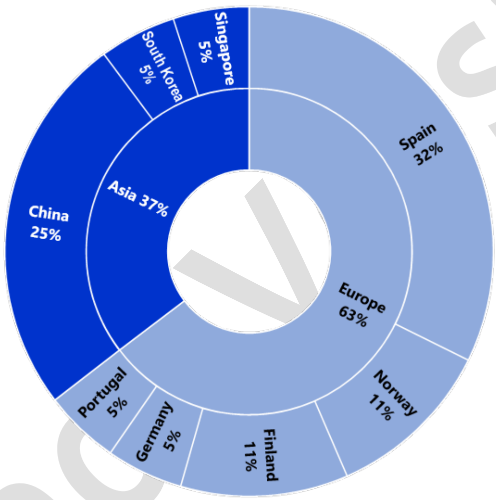

Figure 2 Geographical location of the included studies targeting scaffolding practices in English-CLIL science classrooms.

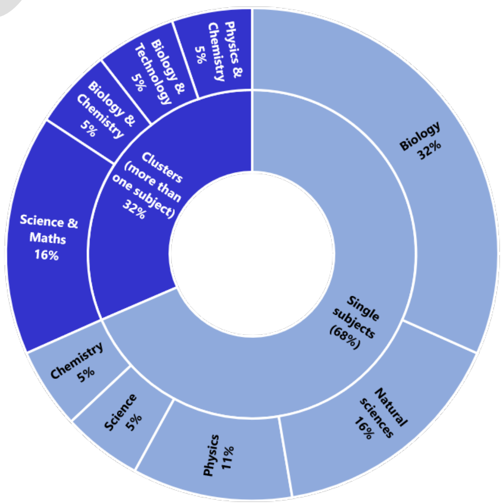

Figure 3. Science subjects in the studies where scaffolding practices were reported.

5.2. Observed forms of scaffolding

The reviewed studies highlight certain practices as exemplary for scaffolding in science CLIL classes. Unsurprisingly, more than one form of scaffolding emerged in all studies; i.e., different forms of scaffolding are often coupled to adjust input and aid students in focusing on, and producing, the target language (see Figure 4). The findings are synthesized below, offering insights into the multifaceted techniques regarded as particularly important by the authors of the reviewed studies.

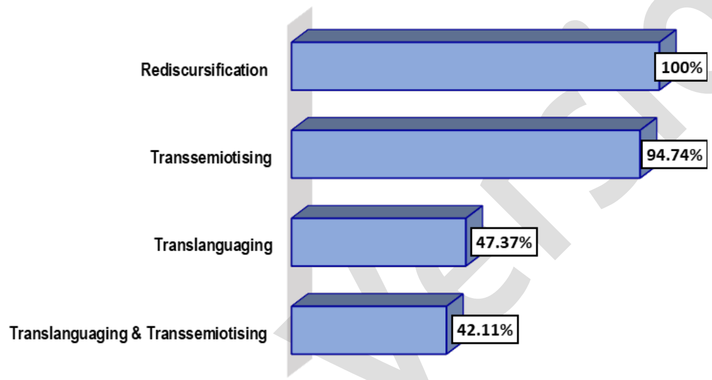

Figure 4. The forms of input adjustment & output scaffolding in the included studies (‘Translanguaging & Transsemiotizing’ refers to studies that jointly employed both constructs in their interventions)

5.2.1. Rediscursification

Scaffolding through rediscursification focused majorly on the treatment of subject-specific concepts in teacher talk, and, on occasion, on general academic terms that are important for content comprehension, and that are principally guided through questioning and explaining to improve science understanding.

5.2.1.1 Employing questions and varying semantic density to facilitate comprehension.

Morton (2015) demonstrated that teachers use display questions to redirect students’ focus from content to language, particularly when detecting lexical challenges during activities. This practice, at times beneficial and other times uncalled for as Morton (2015) cautions, was also applied by the teachers in Escobar-Urmeneta & Evnitskaya (2014) before initiating tasks when a lexical challenge is foreseen. The verbal contextualization of lexicon in these situations includes integrating the word into a sentence, providing students with analytical, grammatical, and syntactic explanations, and contrasting lexical meanings, as seen in Pinho Ferrer (2021). Mahan (2020), however, highlighted that reliance on yes/no display questions result in shorter instructional sequences, which, in her opinion, are less conducive to deep learning, thus recommending a cautious approach to such questions.

Evnitskaya and Morton (2011) described how teachers recast everyday words used by students into scientific labels (e.g., tail vs. flagellum), supporting student socialization into disciplines. These recasts, often paired with questions, enable students to execute subject-specific academic functions, such as measuring and calculating in Chemistry (Nikula, 2015), or enhance word recall (Morton, 2015).

To aid comprehension as well, teachers in several studies (Escobar-Urmeneta & Evnitskaya, 2014; Nikula, 2015; Morton, 2015; Kääntä et al., 2018; Mahan, 2020; Lo et al., 2020) have simplified dense terms by providing definitions, explanations, or examples in everyday language, thereby facilitating access to scientific content. Particularly, Lo et al. (2020) investigated methods to de-abstract scientific concepts, highlighting a limitation in repacking them into instructional discourse, which may obstruct knowledge building.

5.2.1.2 Employing questions to encourage precision and extended production.

Moving from scaffolding input to scaffolding processing and output, questions were found to play a pivotal role in promoting precision and production of science-specific terms. Escobar-Urmeneta and Evnitskaya (2014), Morton (2015), and Nikula (2015), Mahan et al. (2018), and Mahan (2020) showed that teachers continued to probe students further, even after eliciting displays of understanding, with the aim of encouraging them to produce more precise terms. As students' answers unfolded, they were integrated again in teachers' follow-up questions. Questions that target the labeling of objects and concepts, as depicted in Tagnin and Ní Ríordáin (2021), are considered pivotal for building science knowledge and developing scientific language. Their findings also demonstrated that questions providing higher order cognitive engagement are inseparable from extended language production, noting their effectiveness especially when they draw on students' prior answers. Likewise, Mahan et al. (2018) highlighted the employment of open-ended questions in high-quality conversations, enabling students to participate in more extended turns. Teachers, in these scenarios, took up students' responses, requesting justifications and thus, fostering increased student speaking time and engagement in higher-order thinking. In addition to focusing on lexis, Evnitskaya and Morton (2011) highlighted the role of questions and answers in sequencing explanations in interactional stretches with students.

5.2.2. Translanguaging

Studies that explicitly refer to translanguaging include Pinho Feller (2021) and Tagnin and Ní Ríordáin (2021) from Europe, and Wu and Lin (2019) from Asia. Pinho Feller (2021) investigated translanguaging and scaffolding strategies in primary education, highlighting teachers' flexible use of L1 (Portuguese) to teach content, with students' use of English continuing to improve over time. Translanguaging was seen as a pedagogical tool enhancing cognitive processing and critical thinking in CLIL contexts. In upper secondary education, Tagnin and Ní Ríordáin (2021) consider that normalized translanguaging practices in science facilitate access to scientific dialogue by creating a space for students to elaborate their thoughts, build meanings dialogically, and overcome conceptual gaps. Wu and Lin (2019) additionally highlighted translanguaging's role in enabling knowledge co-construction between teachers and students, building thematic patterns and semantic relations within the target subject matter. These studies conceptualize translanguaging as a continuum of linguistic and multimodal strategies leveraged by teachers for effective meaning-making.

In the other included studies, scientific meaning was also partially negotiated in the students' first language (L1). Teachers offered translations for specific or academic terms, from English (L2) to the L1 and vice versa (e.g., Mahan et al., 2018) to clarify specific content and to double-check students' understanding (e.g., Morton, 2015), or because the students have to learn the content in both languages (Pinho Feller, 2021), as well as for more effective engagement (Lo et al., 2020). It is also noted that when teachers accept students' use of L1, they may then target specific terms and reincorporate them into their answers (recasts) in English (Evnitskaya & Morton, 2011), reformulate students' L1 and colloquial L2 responses into L2 academic language (Lo et al., 2020), make use of cognates for positive transfer between languages (Escobar-Urmeneta & Evnitskaya, 2014), and request precise translations to ensure accuracy (Escobar-Urmeneta & Evnitskaya, 2014; Mahan 2020). Escobar-Urmeneta and Evnitskaya (2014) problematize explanations by translation that do not put the translated words in sufficient context, noting that students may vaguely recognize the words in their L1 (also noted to occur in Nikula, 2015), and students in these cases do not form cognitive-semantic representations of the translated words that enable deep learning.

5.2.3. Transsemiotizing

All studies except Tagnin and Ní Ríordáin (2021), given its sole focus on teacher questions, mentioned that paralinguistic modes of communication complement and elucidate meaning. Some studies briefly listed these resources as a means of scaffolding in science lessons (e.g. Kang et al., 2010; Pinho Feller, 2021; Mahan et al., 2018,), while others centered on one mode, or more, in a quasi-experimental set up (Gómez Ramos et al., 2022; Roca de Larios et al., 2022; Wu & Lin, 2019).

5.2.3.1. Integrating paralinguistic resources and verbal support for meaning making.

Iconic whole-body movements and hand gestures by the teachers were salient features in Evnitskaya and Morton (2011), Morton (2015), Kääntä et al. (2018), Wu and Lin (2019). These gestures when synchronised with verbal instruction are regarded as a didactic tool that complement meaning-making (Kääntä et al., 2018; Wu & Lin, 2019). However, when such gestures are used in isolation, particularly when the teacher appears to lack lexical knowledge, they function more as compensatory mechanisms (Evnitskaya & Morton, 2011; Morton, 2015).

Delving deeper, Wu and Lin (2019), applying Multimodalities-Entextualisation Cycle (MEC) developed by Lin (2010; 2015), concluded that integrating whole-body movement and L1 (Cantonese) at the beginning of the lesson enhanced sense-making. The coupling of these resources helped the students to better understand and relate to new information by connecting it to familiar semiotic and cultural patterns in their daily experiences.

Furthermore, ‘prosody’, highlighted by studies from Escobar-Urmeneta and Evnitskaya (2014) and Kääntä et al (2018), was reported to enable teachers to use rhythmic marking to emphasize, negate, or assert specific information, enhancing nuance and clarity in learning.

5.2.3.2. Integrating and sequencing multimodal resources with verbal support for knowledge construction.

The integration and sequencing of multimodal resources with teacher talk stands out in science CLIL lessons. For knowledge co-construction and to reinforce learning through repetition, the teachers in He and Lin (2019) used Concept and Language mapping—CLM pedagogy (a combination of concept maps, cards, sentence-making tables and essay writing guides, highlighting thematic lexical items and patterns for students to notice) to maximize students' exposure to re-presentations of topical knowledge in different modes: talking, reading, doing, and writing. The 'repetition with variation' through the CLM model, the sequential animation with which the thematic items appear one at a time and in sequence from simple to complex, helped make visible the semantic relations within and between subject-specific concepts for students to establish conceptual interconnections and thematic patterns across different lessons. Similarly, Ho et al. (2019) deployed concept sketches and language mapping prior to writing. The iterative intervention drove teachers to seek continual clarifications, thereby refining students' reasoning and explanatory skills regarding their sketches, sharpening students' focus on verbal production and language precision.

Moreover, recent findings by Gómez Ramos et al. (2022) and Roca de Larios et al. (2022) shed light on the effectiveness of graphic organizers in enhancing text comprehension and production. Concerned with the higher frequency of nouns in longer abstract decontextualized science texts which pose a comprehension challenge for lower proficiency students, Gómez Ramos et al. (2022) explored if using graphic organizers (tables, Venn diagrams, and concept mapping) helped students identify lexical categories, especially nouns, and hypernymy-hyponymy relations in four short science texts. Despite the observed improvement on the treatment group's performance on one of the texts, they continued to confuse adjectives and verbs for nouns, and the differences between the treatment and the control groups were not significant, which the researchers attributed to the short implementation of the intervention (3 lessons in one week).

To help students activate and summarize their knowledge of 'levers', Roca de Larios et al. (2022) utilized Cognitive Discourse Functions (CDFs)—a CLIL heuristic by Dalton-Puffer (2013)—to design pictorial prompts and cloze-writing templates. These resources aimed to assist students in defining and classifying levers in written reports. After a three-week intervention, 75% of students could independently produce varying degrees of successful reports on levers.

Finally, several studies have mentioned the use of various multimodal resources more informally, including diagrams for explanatory purposes (Evnitskaya & Morton, 2011), scientific objects and equipment for observation and hands-on experimentation (Evnitskaya & Morton, 2011; Kääntä et al, 2018), and supportive visuals, both still and animated (Mahan et al, 2018; Mahan, 2020; Lo et al., 2020).

5.3. Contexts and cultures affecting scaffolding

Our analysis, grounded in the cultural dimensions outlined in section 2.3 and drawing on Flowerdew and Miller (1995), identifies four cultural dispositions influencing scaffolding practices and their success.

5.3.1. Ethnic culture

The role of ethnic culture in shaping scaffolding is exemplified through the reported reactions of the students to employing a multimodal scaffolding model. Lin's (2015) MEC model was applied in both Tsang (2020) and Wu and Lin (2019). This model sequences and alternates verbal and written texts with diagrams, demonstrations, videos, and scientific experiments. The students in both studies share the same ethnic culture and are around the same age (≈15), yet the intervention was discussed in a positive light in Wu and Lin (2019) only. Tsang (2020) however reported that language-based activities such as text deconstruction and sentence-completion did not encourage participation. This was attributed to the students being from a test-taking culture that prioritizes tackling content-specific exam questions, disabling the students from seeing the connection between the promotion of scientific literacy—exemplified in the applied intervention—and the type of questions they must answer in exams. This critique finds resonance in Lo et al.'s (2019) exploration of another Chinese CLIL setting, where the predominant emphasis of assessments on cognitive demands and content knowledge resulted in diminished motivation for explicit language scaffolding in science lessons. Such resistance may stem from a misunderstanding of the integral role that language plays in deepening content comprehension.

5.3.2. Academic culture

Illustrating how academic culture varies by CLIL setting, Kang et al. (2010) focused on the teaching styles and techniques of Korean and native English-speaking (NES) science teachers. The study critiques the scaffolding practices of NES teachers for their particular interest in defining terms and providing and requesting examples from the students when explaining. This tendency, attributed to language barriers, compels foreign teachers to find multiple pathways to convey the message and ensure comprehension, which, in their view, affects the depth of content covered and knowledge conveyed, unlike the case of local teachers. While NES teachers frequently prompted students to provide reasons for and explanations of concepts and their relationships, local Korean teachers more commonly sought comprehension confirmations. The study shows that teachers' academic cultures influence their perceptions of effective teaching and scaffolding in CLIL environments. Another manifestation of academic culture at play can be seen in Tsang (2020), who, in addition to the students' unmotivated attitude towards the intervention, reported difficulties in planning time and space for the incorporation of multimodal resources, which could be attributed to the institutions' readiness to incorporate multimodal resources with ease into the classes.

5.3.3. Local culture

The studies also showed variation in how L1 was regarded, which we attribute to the local culture. Kääntä et al. (2018) observed that code-switching to the first language (L1) by the teacher rarely occurred in their Finnish study context. In this context, English is typically used without issue as the primary language of instruction during main classroom activities. The few instances of shifting to L1 in this study, mainly by the students, were considered a bilingual setting phenomenon rather than a communicative need. This is not the case in other contexts, however. Tagnin and Ní Ríordáin (2021) and Tsang (2020) emphasize that students in the contexts of their study (Italy, China) do not always possess threshold linguistic resources to participate in cognitively engaging and productive interactions, for which teachers use L1 as a mediating tool to aid cognition and for overcoming conceptual gaps to learn the target subject. Tsang (2020) also adds that: "they [students] need to translate what they have learnt in English to their L1 for practical storage as long term memory" (p. 149). This variation shows that the L1 can serve dual roles within CLIL environments: as an inherent component of learners' linguistic repertoire and as a scaffolding tool, the prominence of which is determined by both students' and teachers' linguistic readiness. In settings where bilingualism is more balanced, L1 use naturally integrates into communication. Conversely, in contexts with lower English proficiency, L1 becomes a scaffolding tool to bridge understanding and access subject knowledge. Another feature of local culture that is at play in scaffolding is when teachers use local examples to clarify scientific concepts. An example from Wu and Lin (2019) shows the teacher using a Cantonese analogy about 'losing water' and 'getting water' to explain the concept of 'transpiration pull' in plants. This analogy reflects the local culture by integrating familiar, everyday concepts with scientific teaching, thereby making complex biological processes understandable and relatable to the students.

5.3.4. Disciplinary culture

Subject specificity also appeared to affect the scaffolding strategies employed by teachers. Nikula (2015) found recurrent differences in the type of actions requested by the Chemistry teacher ('observing' and 'writing down') and the Physics teacher ('measuring' and 'calculating'). Mahan et al. (2018) regarded Science lessons as more complete in concepts and three times richer in visual representations than Maths, rendering the type and frequency of use of supportive visuals different in both subjects. Similarly, Mahan (2020) noted that scaffolding strategies—to connect new and previous knowledge and define new terms—were used more for content comprehension than task completion in science and were very limited for metacognition. Clearly, disciplinary differences affect scaffolding strategies and the type of student engagement in CLIL settings, with subject-specific demands shaping the choice and application of visual aids and instructional actions.

6. Discussion

This section summarizes the research findings in light of the reviewed literature. It highlights teaching ramifications to provide specialists in the field (e.g., pre- & in-service teachers, teacher educators, and CLIL trainers) with an inventory of research-based practices to scaffold science CLIL instruction.

Regarding *rediscursification*, several strategies align with Lorenzo's (2008) framework, leveraging questions, recasting, and also modulating semantic density to navigate lexical challenges that affect content comprehension (see 5.2.1.). Display questions (e.g., Escobar-Urmeneta & Evnitskaya, 2014; Morton, 2015) were found to help teachers navigate lexical intricacies at the input stage. These, coupled with recasts and simplified everyday terms provide means to alternate students' focus between content and language as the need arises, balancing the emphasis on both content and language. Open-ended questions, in addition, appeared to facilitate deeper understanding post initial-comprehension stage. Several studies (e.g., Mahan et al., 2018; Mahan, 2020) point to the importance of skillful questioning, emphasizing that probing students' answers is conducive to knowledge building as it prompts students to elaborate and use more precise terms. In fact, in a recent study by Llinares and Evnitskaya (2021) they affirm that this probing induces dialogicity and extended language production, a prime goal in CLIL for language acquisition.

An explicit objective of CLIL is that students learn the target language, which includes technical and academic lexis. Consistent with Lemke (1990), it is unsurprising that most studies (section 5.2.1.) focused on the handling of subject-specific vocabulary, highlighting not only authentic challenges posed by scientific terminology, but also the foundational role of precise labeling and concept naming in constructing scientific knowledge (Tagnin & Ní Ríordáin, 2021). Consequently, instances observed in our analysis showed that teachers almost always focused on clarifying and consolidating the language of science in English, not general English, avoiding unnecessary digressions into irrelevant vocabulary. In episodes of skilled scaffolding, teachers were also noted to transit smoothly from content to language when required without putting a demand on content teaching time. This seamless integration results from meticulous planning (e.g., Roca de Larios et al., 2022) and from the teachers' own capability to navigate the dual focus on the content and its language requirements (see Morton, 2015).

Good teaching in science also presupposes that teachers can identify problematic language areas that may affect comprehension of the content and know when and how to intervene. The reluctance to do so may stem from the belief that exposure to the language of the subject will suffice for learners to acquire the target language (Hu & Gao, 2021), thus prioritizing focus on content. This can lead students to have a weak command of the scientific discourse required for deeper learning (Meyer et al., 2015). It is therefore crucial for science teachers to focus on language and introduce activities for students to verbalize scientific concepts in the target language, not only to unpack new knowledge but also to repack it using appropriate scientific terms and register (Lo et al., 2020).

The reviewed studies accentuate as well the significance of multilingual practices and transsemiotizing resources in English science instruction. Discussions on students' L1 emphasize it as a crucial cognitive tool for meaning-making (see 5.2.2.), aligned with Lemke and Lin (2022) and García (2009). L1's role is multifaceted, acting as both a natural linguistic code for proficient bilinguals and a vital scaffolding tool for emergent bilinguals, supporting content comprehension and curriculum engagement across varying linguistic proficiency levels (Wu & Lin, 2019; Lo et al., 2020; Kääntä et al, 2018). We observed that in settings where bilingualism is more evenly distributed and students and teachers navigate between languages fluidly, L1 is portrayed as a natural and inherent part of their interactions. This spontaneous use of L1 reflects the cultural and linguistic norms of a bilingual setting, rather than a deficiency in second language proficiency (e.g., Kääntä et al., 2018). Regarding transsemiotizing, the studies illustrate how verbal support is effectively integrated with paralinguistic elements and visual aids to enhance learning, as shown in the teaching sequences of some studies (He & Lin, 2019; Roca de Larios et al., 2022) (see 5.2.3.).

The main implication for teaching with regards to translanguaging and transsemiotizing is that all resources should synergize to convey a more comprehensive message. In addition, previous research suggests that combining verbal and visual systems boosts message retention and retrieval (Paivio, 1986). Thus, various didactic tools, including teacher talk, gestures, and visuals, should complement each other for effective meaning-making. (e.g., Kääntä et al., 2018; Wu & Lin, 2019) rather than settle for the idea that one form (e.g., non-verbal) can compensate for the absence of another (e.g., verbal), as seen in some studies (Evnitskaya & Morton, 2011; Morton, 2015). In this context, it becomes apparent that both teachers and students are encouraged to use all available tools 'to do science' (Lemke, 1990), recognizing that all modes of translanguaging and transsemiotizing are valuable for emergent bilinguals (e.g., Tagnin & Ní Ríordáin, 2021; Tsang, 2020).

Furthermore, translanguaging not only supports metacognition, metatalk, and private speech (García & Li, 2014, p. 90) but also prepares students for more effective learning in CLIL environments. This is particularly important because CLIL students, as L2 learners with limited exposure to the target language outside the classroom, benefit greatly from using all modes of communication and interaction available in the classroom. By doing so, they can extend their learning capabilities beyond what they could achieve independently (Vygotsky, 1978). Nonetheless, it is essential for teachers and teacher trainers to critically distinguish between linguistically proficient bilinguals using all available resources to enhance their messages and emergent bilinguals who may become accustomed to compensating for their L2 limitations through other means.

Additionally, as students rely on teachers' verbal input, and emulate it, it is advisable that teachers reflect on the effect of the verbal adjustments they make.

Finally, our analysis points to a symbiosis between macro scaffolding forms and cultural dimensions. Ethnic cultures that are driven by performance metrics that value high test scores and rote memorization could give rise to academic cultures that disfavor multimodal forms of scaffolding (e.g., Tsang, 2020), curtailing their benefits (see 5.2.3. & 5.3.). Furthermore, local cultures appear to influence how teachers regard translanguaging practices (e.g., Kääntä et al., 2018) (see 5.2.2.) and disciplinary cultures appear to also influence the choice of transsemiotizing techniques, highlighted in the particularities of scaffolding in Chemistry and Physics for example (see 5.3.3.). The final teaching implication is thus to address the interplay between cultural dimensions and academic practices, by choosing culturally responsive scaffolding practices that allow opportunities and time for students to experience the benefits of the approaches that they are not accustomed to.

Building on the insights from the discussion, a succinct description of scaffolding in CLIL science education is synthesized. It integrates rediscursification, translanguaging, and transsemiotizing practices to facilitate not only the comprehension and production of scientific content, but to encourage higher-order thinking and deepen understanding of scientific concepts. These scaffolding practices are influenced by students' diverse cultural dispositions and linguistic capacities, necessitating tailored approaches to effectively support learning.

7. Conclusion

This study contributes to the field of CLIL science teaching by synthesizing a decade of literature on the topic. It presents insights into how scaffolding practices, linguistic and non-linguistic, are employed in observed classes across diverse, Asian and European, content-driven CLIL contexts. These scaffolding practices embody acts of rediscursification, translanguaging, and transsemiotizing, reflecting contextual and cultural nuances and variations. Thus, another research avenue emerging from this study involves examining how CLIL contexts, representing different cultural environments, warrant that specific scaffolding practices would be regarded as more, or less, effective than others, as shown here. Also, the role of L1 varies with the perceived difficulty of science in English and students' customary bilingual practices, illustrating the adaptability of L1's role across different educational settings. While the role of L1 and paralinguistic resources are already established for enhancing communication (e.g., Pinho Feller, 2021; Moore & Nikula, 2016), further research may explore the extent to which they boost science literacy versus serving as compensatory strategies where L2 proficiency is limited.

In addition to actionable recommendations, this study has also provided a succinct synthesis that describes scaffolding in CLIL science subjects (refer to the Discussion section). We hope both contributions —the recommendations and the synthesis—can foster ongoing dialogue about enhancing subject-specific literacy skills in general, and specifically in science instruction.

Our study also reveals a scarcity of experimental studies, highlighting a predominance of exploratory ones. This implies that our recommendations are mainly drawn from observational insights and the interpretations of researchers, presenting a limitation in our study. Our search produced a limited number of studies that employed frameworks for the integration of content and academic language learning in instruction (e.g., He & Lin, 2019; Roca de Larios et al., 2022; Tsang, 2020; Wu & Lin, 2019), despite their increasing use in analyzing CLIL students' academic performance in science and establishing success criteria (e.g., Llinares & Nashaat-Sobhy, 2021; Morton

& Nashaat-Sobhy, 2023). Lin's (2010; 2015) Multimodalities-Entextualisation cycle appears to enjoy slightly more representation than other frameworks though, particularly used to enhance understanding of science classroom interactions in the secondary stage in Asian settings. Hence, future research should focus on intervention studies using these frameworks to address CLIL learners' content and language integration problems in varied contextual settings.

Another key observation is the limited focus on broader aspects of scientific literacy, with most studies concentrating on subject-specific vocabulary challenges, echoing Lemke's (1990) emphasis that engaging deeply with scientific concepts requires an understanding of thematic patterns and semantic relations, which are equally important. In line with our findings on the interrelation of scaffolding forms and disciplinary cultures to support literacy development and knowledge-building (5.3.3.), further explorations into literacy demands, scaffolding forms in different sub-areas of natural sciences, and the purposes of transsemiotics are needed.

In conclusion, the study accentuates the necessity for a balanced and deliberate use of various semiotic resources in CLIL science instruction. It advocates for an increase in context-specific intervention studies to connect actions to outcomes and also to cultural dimensions that enhance academic performance in CLIL environments.

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