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Can "Integrated Learning" with English support science education? A case study in Portugal

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Abstract
Content and Language Integrated Learning (CLIL) is an approach used in different countries for learning foreign languages (FL) during non-language classes. Studies suggest that teaching methodologies aware of (verbal) language–such as CLIL–and other science modes (operational, symbolic, visual, etc.) can be beneficial for learning science. Within this PhD research, we aimed to understand science education practices and the influence of English (as a FL) on CLIL science teaching/learning. We designed a qualitative case study in a Portuguese school and gathered information through different methods. We found that, because English is present, a science teacher may become more open to the students' (language) learning difficulties and to changing strategies/resources. Besides promoting FL proficiency, CLIL could represent a language-aware approach for enhancing science teaching/learning. This contributes to studies on CLIL and science education with a language focus and opens a reflection on teacher practices/education for the learning of science.

Keywords: Content and Language Integrated Learning (CLIL), English as a Foreign Language (EFL), language-focused science education, lower secondary school, qualitative research, scientific literacy

INTRODUCTION

Students' scientific literacy and proficiency in Foreign Languages (FL) constitute global educational concerns. While in the last century science, medicine, and technology have been evolving, "transferability" of school science knowledge into "comprehension" of everyday natural phenomena has been poor, as reported for example by OECD's PISA (2015), giving rise to a "general debate on the need for a sufficient level of scientific literacy and the necessity to improve the quality of science instruction in school" (Duit, 2007, p. 3). A scientifically literate person should be able to understand and integrate scientific information, engage with and take responsible decisions about socio-scientific issues (Holbrook & Rannikmae, 2009; Roberts & Bybee, 2014) and "navigate" (mis)information to form opinions on that information, Howell and Brossard (2021) expand. Therefore, in the words of Holbrook and Rannimkae (2009), "a familiarity with language, or communication tools in general, can play a role […] to know how to extract and handle information" (p. 282).

Language is central in science teaching and learning, having a role in knowledge construction in the science classroom, which is supposed to be an interactional space for making sense of experience and participating in communities of practice (Espinet et al., 2012). In fact, meaning making activity occurs in science classes, according to Bezemer and Kress (2020) and Lemke (2003), through a diversity of semiotic resources, representation modalities or languages[1]. Nevertheless,

This study is derived from the PhD thesis of the first author.

[1] Their meaning is broader than specialized languages of biology or physics, since they represent/communicate science concepts and processes through different languages or resources: verbal (spoken and written), visual (graphs, tables, diagrams, drawings),

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Contribution to the literature

- The purpose of our research was not to improve science education by itself nor to understand the foreign language enhancement through CLIL (Content and Language Integrated Learning); rather, it was to study CLIL science practice as a language-aware environment beneficial for science education.
- This study shows that the foreign language presence makes the teacher perceive the existence and difficulties of the science languages.
- CLIL is relevant to science education and we make the first such contribution to this journal.

the learning of the science language(s) can be, for many students, a major difficulty, as claimed by Lemke (2003) and Wellington and Osborne (2001). Science communication and its languages should thus be emphasized over facts and formulas and addressed as a fundamental competence, acknowledging that the learning of the language and literacy practices have to be confronted as an essential part of science education (Pearson et al., 2010; Polias, 2016).

On a different level, for people participating in scientific and general discussion, being competent in FL (albeit to varying degrees) is also fundamental (European Commission, 2003). Global demand for learning English and learning through it has been increasing due to being the language of the international scientific community, of technology and multimedia, and useful for professional mobility and cultural encounters (Gimeno et al., 2010; Marsh, 2006). English language skills have become a paramount competence, especially for scientific degrees. Hence, the relevance of creating conditions for meaningful English learning and of exploring how English might support the learning of science and vice versa, for instance when "integrated" as a non-native language during science classes within cross-curricular programs, is defended by Piacentini (2021).

The "Content and Language Integrated Learning" (CLIL) educational approach has been practiced in European countries within these programs, initially, to promote FL learning, frequently English, as Cenoz (2015), Dalton-Puffer (2011), and Lasagabaster and Sierra (2010) remind. While the theoretical underpinnings and methodological concerns of CLIL arose almost 50 years ago from immersion programs of Canadian bilingual education, the term was coined by Maljers and Marsh only in 1994, and differences have appeared over time, such as the teachers' and students' "non-nativeness", lower time of exposure and readapted or supporting materials, among others (Lasagabaster & Sierra, 2010). In later works (e.g., Dalton-Puffer, 2011), CLIL would be viewed as an "umbrella" term for those educational practices and settings where non-language classes are taught through the medium of a language other than the mother tongue (L1). It is based on the principle that languages are learnt while they are "naturalistically" used within discipline classes and directed at students' learning of both the additional Language (foreign or second) and specific subject Content (the whole syllabus or part of it) (Coyle et al., 2010; Marsh et al., 2011; Pavón Vázquez & Ellison, 2013).

The dual focus on Content and Language requires "hard work" of teachers and students (Bruton, 2013), the former encountering professional and personal challenges teaching with/in the FL (Blanchard et al., 2014; Grandinetti et al., 2013), the latter facing the cognitive demands of a given activity (Dale & Tanner, 2012). On the other hand, CLIL implementation entails authentic learning conditions and strategies more centered on learners (Dale & Tanner, 2012; Grandinetti et al., 2013; Mehisto, 2012), even though this positive change in classroom pedagogies is not guaranteed (Dalton-Puffer, 2011). Numerous studies have shown that CLIL students become more proficient in the target language (see Dalton-Puffer, 2011) and can improve their attitudes and motivation towards FL learning (see Pavón Vásquez & Ellison, 2013). Research has shifted only recently to concerns related to the CLIL learners' acquisition of the target disciplinary knowledge (Meyerhöffer & Dreesmann, 2019) and more studies should be conducted in different settings to achieve a comprehensive vision of CLIL, as Fernández-Sanjurjo et al. (2019) warn.

Specific works (e.g., Blanchard et al., 2014; Canet Pladevall & Evnitskaya, 2011; Grandinetti et al., 2013; Valdés-Sánchez & Espinet, 2020) suggest that CLIL science practice can also be beneficial for science education and conceptions of science. Moreover, this practice may represent a research context to gauge the significance of a teaching aware of language (native or non-native) and other semiotic modes implied in science. The (science) teacher's language awareness is a quality advocated by CLIL scholars (e.g., Coyle et al., 2010;

mathematical (formulas, equations, calculations), kinesthetic (action and observation within experimental procedures and operations), etc. (Lemke, 2003). According to Cope and Kalantzis's (2009) "reconfigured" multimodality, written and oral language are separated and a wider range of modes exists: visual (different from Lemke's (2003) one), audio, gestural, emotional, spatial and including a tactile representation (which would also encapsulate Lemke's (2003) kinesthetic one).

Llinares et al., 2012; Wolff, 2012), but, even when the L1 is used as language of instruction, teachers are not always aware of the learners' difficulty with the science languages (Lemke, 2003; Wellington & Osborne, 2001). According to Seah and Silver (2018), the role of the teacher's knowledge of and strategies for dealing with the language implications of specific topics is integral to students' science learning. Therefore, it is crucial to study CLIL programs nurturing language learning/use within science education. The "English Plus" (EP) project–in which science is taught and learnt with and in English through the CLIL approach at lower secondary school in Portugal–thus, became the object of study of the first author's PhD (Piacentini, 2020).

In order to depict this school articulation between science and English, CLIL EP and non-CLIL science classes were examined, and the participants' perspectives taken into account. This PhD study continued a previous work on stakeholders CLIL EP project of history (Simões et al., 2013), integrating views from CLIL students of different ages on learning/teaching processes (Piacentini et al., 2018) and moving the focus to the educational science field (Piacentini et al., 2016). Its major purpose was to contribute to the understanding of the role of language(s) in science education through the characterization of non-CLIL and CLIL teaching practices–as Piacentini et al. (2019) started–and to propose an instrument for incorporating them in a broader language focus (see Piacentini et al., 2017). However, none of these articles provides a panorama of science education and practice of languages within EP. Hence, the present work has the following research objectives: to characterize participant teachers' and students' both perceptions of science and practices (and languages) of science education (non-CLIL conditions); to understand the influence of English on the science teaching and learning within the project (CLIL conditions).

PORTUGUESE CONTEXT AND LOCAL SCHOOL

In Portugal, in the last 15 years, CLIL practice has been growing, even though projects–and research about them–mostly involve tertiary education. English is the FL most frequently selected among Portuguese CLIL initiatives, both institutional (*Bilingual-Schools-Programme-in-English*[2]) and grassroots, at compulsory school levels (Ellison, 2018; European Commission, 2017). Portuguese people are exposed to English every day through non-dubbed movies and series on television as well as the Internet.

Our empirical inquiry in 2015-2016 was focused on the school-led CLIL "English Plus" project, since in the corresponding school: one integrated learning action (the EP of history) had already been provided and teachers showed availability to continue collaborating with our research unit (CIDTFF); the educational integration comprised the science curriculum; the provision pertained 7th, 8th, and 9th grades (ages 12-14)[3].

Its first edition was undertaken by teachers with students of one class in one state-run school in North Portugal, between 2010 and 2013, and monitored by researchers from our group in terms of stakeholders' perceptions. It was one English teacher (tEng1) who introduced and developed this educational integration as a strategy for language promotion within specific subject classes, collaborating first with one history teacher and later with other motivated teachers. She reactivated the project in 2014-2015 for natural sciences (NS), involving one science teacher (tSci1), and coordinated a further collaboration with the same research group since 2015-2016, the year of our study. During this year, 5 out of 20 classes in the school attended the EP project, with two science and two English teachers. If demand to enroll in EP was too high, students were selected on (English and NS) merit; after 2016-2017, all requests have been accepted.

EP students' weekly scheduled class time was:

1. 45', theoretical NS with English (co-teaching: both subject and language teachers were present and using English),
2. 45', theoretical NS held mainly in Portuguese (single-teaching: classes given by the non-language teacher alone, who could opt for Portuguese but also English, sometimes deploying project-like strategies) and
3. 45', project time (PT, school project option implemented by the language teacher, who gave English through science topics).

As described by Piacentini and Simões (2022), EP English and science teachers also had co-planning–working together on the project implementation and material construction/revision–available once a week in their timetables, when possible. Science teachers would make changes to the normal NS plan (in its order or adjusting topics); also, according to the content topic, they could choose suitable units to teach with the use of English, rather than covering the whole syllabus. EP teachers systematically organized extra-curricular activities for and with their students.

[2] This program currently involves 28 state school clusters; for further information, see http://www.dge.mec.pt/programa-escolas-bilinguesbilingual-schools-programme

[3] In these grades corresponding students' FL skills are expected to be more advanced than in previous levels and an established separation of curricular areas, started in the 5th+6th, exists, justifying a program articulating a subject with another language.

RESEARCH METHODS

Design and Participants

The ideal design for fulfilling our research objectives was a qualitative case study, to investigate "a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident" (Yin, 1994, p. 13). The curricular integration of science and English could not actually be separated from the project conditions and its participants. However, we chose and examined the EP case because it could play a "supportive role [helping] us pursue the external interest" (Stake, 1994, p. 237), in the language(s) used within the science discipline and how the presence of English could affect them. Hence, we designed a descriptive-explanatory case study in 2015-2016. An extensive observation was carried out, and teachers and students associated with the project at different times and levels, were "embedded" as subunits of analysis of a single case.

In 2015-2016, two science teachers (tSci1, tSci2) and two English (tEng1, tEng2) teachers were involved in the project and in our inquiry:

1. tSci1 was the NS teachers of the two 8th grade and one 9th grade EP classes and tSci2 of the two 7th grade ones, in the year of the study; in 2015-2016, tSci1 was in her second year of the EP project of science and tSci2 in her first one;
2. tEng1 was the English teacher of these five classes and had played a pivotal role in the 2010-2013 EP of history and in reactivating the project for NS in 2014-2015; tEng2 was "tutored" by tEng1 in 2015-2016 and had her own EP class the year after.

With regard to the students, the following profiles existed:

1. 11 "former" students–high school students in 2015-2016, who had had EP history in 2010-2013 (when they attended the project at lower secondary school);
2. 96 "current" students–lower secondary students provided with EP science in 2015-2016 (7th and 8th graders in their first and second year of the project).

Data Collection and Analysis[4]

Since our research was grounded in the Portuguese context, we used Portuguese enabling teachers and students to build up a rapport with the researcher, feel comfortable in understanding questions and expressing themselves fully. In relation to data to be obtained from questionnaire and classroom observation the spokesperson teacher delivered a form for families to authorize their daughters'/sons' involvement in the study, with its data collection and guarantee for participants. Teachers and former students gave their oral consent before the interview itself. We kept personal information confidential.

Roman numerals in the text will highlight strategies used to ensure the credibility of this qualitative inquiry (issues of validity adapted from Merriam, 1995). Data were collected from a diversity of sources (teachers, younger and older students; different times and settings) and through multiple techniques (I), as described below.

Teacher interview (tINTER)

We designed one semi-structured guide for tSci1 and tSci2 and one for tEng1 and tEng2, differing only in the items about the learning experience with science, FL knowledge and implications of relative disciplines (see Appendix A). The first part of the guide contained questions with respect to the interviewees': (i) education and work as a teacher; (ii) linguistic/scientific profile; (iii) strategies and resources used in classroom practices and (iv) vision on socio-cultural implications of the subject they teach, as well as (v) opinion on associating science with (foreign) languages. The second group of questions referred to (vi) knowledge and/or experiences they have with the CLIL approach in the EP project, at an organizational and educational level; some of these were broadly based on "the CLIL teacher's competences grid[5]" (II). Colleagues with teaching experience were test-interviewed to validate questions and the interviewing process (III).

Current student questionnaire (sQUEST)

Because of the large number of current EP students, we developed a questionnaire. It was reviewed, independently, by two experts (from language and science education research fields) and piloted on one 7th grade class (attending an EP-like project in the same school district) (III); then checked by teachers (IV) and administered through a Google Drive form[6]. The 21 questions (10 closed-ended and 11 open-ended) aimed at understanding the students': (i) school profile; (ii) language repertoire; (iii) experience with "science + English" out of school; (iv) relationship with (the learning of) English and languages (v) as well as with science; (vi) difficulties encountered in science classes; (vii) suggestions to science/English teachers to improve students' learning; and (viii) opinion about EP, its

[4] The Portuguese GDPR only became applicable in May 2018. An ethics committee exists in our university, but it does not accept retroactive requests.
[5] For further information, see http://tplusm.net/CLIL_Competences_Grid_31.12.09.pdf
[6] Link only for the reviewer/reader (editable version without data): https://docs.google.com/forms/d/1Bml-M5mDj4JCMq1tfVVm6ALKf3kDP2OsAj5jlN5fywk/edit?usp=sharing

Table 1. Issues of validity (adapted from Merriam, 1995).

Validity	Issues
Content validity	II–Literature-based questions (tINTER, sQUEST) III–Question/process pilot (tINTER, sQUEST)
Internal validity	I–Triangulation of sources/techniques IV–Participatory research modes (sQUEST, sINTER) V–Long-term observation VI–Peer examination (of project design, coding, etc.)
External validity	Sections *Portuguese context and local school*, *Results*, and *Appendices* provide a "thick description" of this CLIL approach and "modal comparison" between non-CLIL and CLIL conditions which allow the reader/user to determine whether findings can be transferred to other situations, and also to grasp what works in the local context and what applies universally. In terms of usefulness for stakeholders, findings have been made available in the form of scientific articles, presentations, infographics, leaflets, etc. (see the University of Aveiro's RIA repository). Moreover, some Portuguese schools interested in the CLIL approach have consulted with our group; to some extent, they can depend upon the information in our study.

advantages and obstacles. Questions related to (ii) and (viii) and to (vi) were based on the instrument developed by Simões et al. (2013) and on science teaching practices delineated by Vieira (2018), respectively (II).

Former student interview (sINTER)

Taking into account the maturity and small number of former EP students, we constructed a semi-structured interview guide (see Appendix B), together with their former English teacher (tEng1) (IV), in order to understand: (i) the older learners' opinion about the project; (ii) difficulties encountered and overcome as well as suggestions for current students; (iii) which discipline(s) benefitted from this educational combination; (iv) differences between co-teaching and single-teaching; (v) situations in which the English use could have facilitated learning; (vi) possible benefits for the study of science at high school; and (vii) learning of English and desire to know other languages and cultures.

Observation of planned/implemented classes for current students (OBSV)

To corroborate evidence from the above-described primary data sources about the EP school organization and science educational practices, we reviewed the first author's observation logbook. This shifted from a more narrative to a more objective form, as the researcher shifted from participant to observant. Observation was performed roughly once per week during five full months (V). Contexts observed were diversified to understand the phenomenon from a variety of angles and until information started to repeat and match from different sources (saturation point) (I, V). We observed NS co-taught classes and English classes on science topics, but also NS practical lessons, classroom debates in English, groups working in class, classroom test correction in Portuguese. We also include NS lesson planning and test design, as well as theatre rehearsals, informal chats, among others.

Documents (DOCS)

To complement information (I), we gathered: the 2015-2016 planning document of the school offer discipline (the EP project); the 2015-2016 report document of EP project (in natural sciences); the 2014-2017 school educational project.

Data collection occurred in 2015-2016, at the beginning (tINTER), in the first and third terms (sQUEST, sINTER), during the whole school year (OBSV), and at the end (DOCS). We formed categories inductively through qualitative content analysis procedures on (audio-recorded then) transcribed interviews (tINTER, sINTER) and on the questionnaire open-ended answers (sQUEST), whereas descriptive statistics was carried out on the closed-ended ones. In the case of content analysis, (science, FL, and general) education researchers validated coding (VI). Validity criteria for the whole inquiry are summarized in Table 1.

Reliability as replication cannot be a criterion for this qualitative study, because we are dealing with an interpretation of the phenomenon, as Merriam (1995) maintains. However, the second and third authors (PhD supervisors) verified that results were consistent with the data collected, throughout the research process, and this was also discussed with other researchers. Furthermore, the PhD student researcher worked on category formation of the same information at different times, "becoming a more reliable human instrument", using Merriam's (1995) words.

We will present and discuss data emerging from OBSV and DOCS as well as from:

1. tINTER–(ii), (iii), (iv), (v), (vi);
2. sQUEST–(i), (iii), (v), (vi), (vii), (viii); and
3. sINTER–(i), (ii), (iii), (iv), (vi)

being relevant to the nature of this article. Findings are labeled in the next section according to the corresponding source/technique. Their corroboration is clear from the diversity of labels present. Data collection

Table 2. Science education in non-CLIL and CLIL conditions

	Macro-descriptors	Micro-descriptors
1. Science (education) practices and perceptions		
	Contexts to learn science	A1, Timetable A2, Projects A3, Outside of school
	Perceptions of science	A4, Teachers' view A5, Learners' view
	Languages of science	A6, Scientific lexicon (in Portuguese) A7, Presence of English A8, Visual constructs and presentations A9, Science activities A10, Subject regardless of the language
2. Influence of English on science education		
	Language (English)	|| B1, Increased proficiency || || B2, Authentic use and greater interaction || B3, Practice of the FL and a. teacher's awareness of difficulties || b. learners' familiarization with it ||
	Integrated Learning	B4, Learning experience through: || co-teaching and PT; extra-curricular activities, membership and family involvement || motivation for the discipline; dedication; etc.
	Content (Science)	B5, Scientific lexicon in English B6, Expanded knowledge of Science B7, Engaging teaching approach through a. alternative strategies and methods b. the use of a different language

instruments and empirical evidence (in italics) were translated by the first author.

RESULTS

The presentation of the results uses two sets of macro/micro-descriptors (Table 2), namely for (i) characterizing perceptions of science and practices of science education (non-CLIL conditions) and (ii) understanding the influence of English on science teaching and learning (CLIL conditions). The "languages of science" of the first set and the B3a. micro-descriptor reflect and expand findings on teaching already published in Piacentini et al. (2019), through delineating different modes/languages for science representation/communication within regular and project teacher's practice and through triangulating previously unpublished evidence from various sources. The "picture" provided by the descriptors from A6 to A10 is also enriched through the students' difficulties with science learning and their suggestions to teachers for improving it found in Piacentini et al. (2016). Macro-descriptors of the second set reorder the acronym of CLIL as L.IL.C (from Language promotion to Content enhancement, see state-of-the-art review by Piacentini, 2021), include some findings of Piacentini et al. (2018) and triangulate new ones within corresponding descriptors. Micro-descriptors between ||…|| are not pertinent to this article.

Science (Education) Practices and Perceptions–Non-CLIL

A1, Curricular timetable

Scheduled class time of theoretical science (co- and single-taught) classes and of the science-based language instruction (the school project option) was understood from OBSV and DOCS, and explained above. Practical NS classes occurred in the laboratory and with half the class at a time (45′ each 14-student-group, while the other worked with the physics-chemistry teacher) (OBSV). The rest of the science timetable also coincided with the standard curriculum (physics-chemistry: 90′ and 45′ of theoretical and practical classes).

A2, Subject-related projects

As described in the school document (DOCS), school projects connected with science and involving students beyond the curricular timetable: promoted healthy life styles, personal and social competences and sex education at school for the prevention of risky behaviors (*hand-in-hand-with-health*); raised awareness about the importance of individual behaviors for the environment and sustainability as well as practice recycling, reduction and reuse at school (*eco-schools*); integrated the scientific, industrial and entrepreneurial areas and promote science and technology (*science-at-school*).

A3, Contexts outside of school

Current students identified contexts where they had experienced science together with English in their daily lives (sQUEST). "English embedded in science" learning spaces (updating Piacentini et al., 2016) provide information also about contexts to "contact" science outside of school:

1. information media–documentaries on science topics broadcast on National Geographic or Discovery Channel, (scientific and not translated) movies, commercials and news available on foreigner or international TV channels;
2. visits and tours–visits during which information in English could be found or English is used to communicate with people speaking different languages, as well as visits within trips abroad or school projects; and
3. other contexts–purchase of commercial products and medicines, students' spare time and families, among others.

A4, Teachers' points of view on science

In tSci1's opinion, science knowledge is constructed all the time, during classes but also outside of the school walls, through everyday experience, with students making sense of life through science classes (*when [students] have questions about anything […] they think that it's in science [classes] that one has to answer*) and teacher learning herself (*students think about what didn't cross our minds and we learn with them […] every day*) (tINTER).

According to tSci2, science knowledge emerges from a process of construction and communication (*science evolves [also through] this great capacity […] to communicate the science that is made [which, from one] scientist, […] becomes an idea of the world*), which could be adapted to science learning, as long as the students' problem posing and conceptual change is promoted. Nevertheless, the science teachers' constructivist perspective of learning by discovery and "problematization" and through actual experimental work has been replaced by the goal of the test score: *[now] the main concern is that [students] get a body of knowledge […] to face the exams [but] experimentation has an extremely important role [for them] to perceive what is done as a scientific construction* (tINTER).

The lack of time to prepare simulations and experiments, few microscopes for all students to use/see and managing large groups were felt by tSci1 to be some of the obstacles restricting practical activities. Moreover, teachers dealing with the planning of science classes maintained that the 7th grade science syllabus (primarily, geosciences) was very abstract and more adequate for the science education of later grades than right at the start of a new educational stage (OBSV).

In terms of culture(s) cultivation in science classes, tSci2 stated that students feel that their "culture" is not represented at school, although some issues of the (former) science curriculum could be explored to understand local resources and traditions, also in relation to those of other cultures (tINTER). Thinking differently, tSci1 interpreted "cultures" as values and attitudes that students develop at home and raise in the classroom (during sex education) with learners having a need for talking about them.

A5, Learners' points of view on science

Some of the former learners chose to continue studying science at high school which required, in one student's mindset, self-confidence and motivation, increased through the EP project activities and challenges: *[the project] allowed me to like science more […] it always encouraged us to improve our skills, so […] it also encouraged us to choose science, at that time the most difficult choice* (sINTER). Similarly, current learners affirmed: *the science course is the most difficult […] the best, I mean, when […] we have in our CV that we [studied] science, [employers] will deduce that we are quite smart*.

Among these younger students (sQUEST), the importance of (the learning of) science lay in enabling the understanding of the natural environment (a-*to know in a more complex way the world we live in*; b-*[through it] we know (almost) everything that happens around us*; c-*we have to know why some things happen in nature and their origin*; d-*to understand how our body and psyche function*). Science was considered to be also holistically present (a-*we can go anywhere [and] everything is science*; b-*there are rules and basic things that we learn in this discipline for life*). Science knowledge was, thus, regarded as fundamental for daily life, and for the science field of future jobs (a-*to be doctors or engineers we need biology or science*; b-*to be geologists, scientists, etc. we have to learn science*) and academic choices (*in all courses science is important*). Furthermore, more than 40% appreciated the science curriculum.

The English teachers' answers in relation to when they had been science learners (tINTER) showed that they studied science until the 9th grade, with tEng2 having experienced beneficial learning based on practical works also applicable in daily life (*laboratory classes [doing] experiments […] in groups with the teacher […] and us executing [classes] of a practical nature, then [I went] to humanities, that experimental part no longer existed [but] knowledge gained at school [I use] every day*). She also stated that some science "practical character" can be positively transferred to English classes. On the other hand, tEng1 recalled science lectures (*[when] I studied there was not so much focus on experimental laboratory work, classes were more expository*), whose "normativeness" endured in her conception of this discipline and attitude with it (OBSV).

A6, Scientific lexicon (in Portuguese)

Scientific lexicon was acknowledged as a language by the English teachers but not by the science ones (tINTER). Also, according to the ex-EP students who studied science at secondary school level, the learning of science involved the understanding of terms (more or less specific), which could be supported by knowing English (sINTER). Understanding scientific terminology was found to be the second most difficult aspect by recent science learners (i.e., 7th graders; sQUEST). One stance among these students with regard to their science teacher is worth noticing, that *some concepts are not really covered in class and teacher takes them as given*, and the class episode on the Earth's structure, during which teacher introduced the term *shear*, unclear even in the L1 (OBSV).

A7, Presence of English

English was referred to by language teachers in general, whereas their subject colleagues mentioned its presence in online resources, videos, magazines, etc. associated with science (education) (tINTER). More specifically, they reported English in the many terms used in science (DNA, HIV, etc.) and in communicating it (*international language […] in science […] a medium to both mobilize and disseminate knowledge*). In the opinion of some former students, English language skills gained through the project facilitated access to and understanding of information useful for scientific studies (a. *the high school biology teacher used many videos in English [from which] I was already able to extract some information*; b. *many articles that we used and studied are in English [and having had] the project made it easier to understand*) (sINTER).

Quotes of "English embedded in science" contexts (see A3) disclosed the role of English in this area (a. *online, while searching about science, I find English words*; b. *when I watch English and American programs on television about science, I find words learned at school*) (sQUEST). The sentence *I see on television that basically all scientists are English* can be linked with this and the conflation of English merely with English speaking countries (aspect revealed by tINTER, OBSV and DOCS). The EP project also aimed to *prepare students for the demands of today's society […] acknowledging English's importance as a privileged communication tool [for the] increasing international contacts* (DOCS).

A8, Visual constructs and presentations

While tSci1 reported using Power Point presentations and short videos during classes and Facebook outside of them, to help learners visually, tSci2 described visual support (images or documentaries) and concept maps as scaffolding strategies recurrent in science education (*visuals help a bit to materialize, [otherwise students] don't see the process […] concept maps overcom[e] limitations of our own language*) (tINTER). Nevertheless, science 8th graders deemed construction of concept maps one of the most difficult issues (sQUEST). Furthermore, the most frequent suggestion given by current students to their science teacher was a higher use of sketches, tables and summaries for organizing (visually) and communicating/understanding the discipline. From observing science single-taught classes, actually, the use of diagrams (of biogeochemical cycles) without description or explanation of its components (arrows with direction and colors, substance formulas, images, etc.) was noted (OBSV). Walls were bare in all classrooms, lacking in visuals to support the learning.

A9, Science activities

Practical activities (lab experiences, visits, etc.) and group works were developed by teachers (OBSV) and also considered as learning settings of science teaching (tINTER). However, current EP students declared frequent difficulties in participating in debates and writing reports, in contrast with hands-on activities, simulations or field trips (sQUEST). Experimental activities were also perceived to be one of the most difficult practices. One simulating lava flow through variables during classes at the lab was a scientific context with linguistic demands (OBSV).

Students suggested that practical and field work be increased in order to learn science better (a-*[with] practical activities it's easier to learn because we see what is happening and understand better*; b-*field trips [make us] understand the discipline in practice helping us to learn the theoretical part*) (sQUEST). Laboratory-like activities were not detected for lessons on ecosystems nor a strategy and material diversification within theoretical classes (OBSV).

A10, Subject regardless of the language

The teaching of all disciplines including science must help students to master their L1, as endorsed by teachers from both areas (tSci2, *a science teacher is a communicator as any other teacher*; tEng1, *the science teacher […] all [teachers] have to help students to master their mother tongue*) (tINTER). The relationship between the language and learning the subject through it–*the language […] as a vehicle of knowledge transmission and […] of learning*–was, from tEng1's perspective, a concept of language applicable not just to science. Moreover, according to her colleague tSci2, *the representation does not have language, [it has to do] with experience.* As clarified by one former student, the learning experience and method learnt within the EP of history helped the study of secondary school science: *a theatre piece improved our oratory skills, [useful for] high school oral presentations […] even if they're in Portuguese, […] in fact the method is independent of the language* (sINTER). For another one, *the project facilitated [science] activities [such as] learning how to debate, search.*

Irrespective of the language spoken in science classes, teachers had different styles in the classroom (e.g., tSci1 used to be still next to the computer desk in front and tSci2 to trace linear movements through the space) and during the planning of or reflection on lessons (OBSV). This discipline has, then, *its experiences, its logics* and it is present *everywhere, observing plants, rocks, ...* allowing *[me], when I'm sick, to know what to do, how to react, what made me end up like this* (sQUEST). Students also suggested that *classes are interactive and fun*, with *more games and activities*, or that *teachers motivate students* and *put themselves in our shoes during the class [to] also be asked some questions*, for improving science learning.

Influence of English on Science Education–CLIL

B3a, Practice of the foreign language and teacher's awareness of difficulties

Much of this information resulted from interviewing teachers (tINTER, see Piacentini et al., 2019). To sustain "science with English" classes, language teachers needed to become acquainted not just with the English version of Portuguese scientific words but also with the concepts of science itself. Actually, tEng1 affirmed: *I do not feel comfortable in science […] sometimes my colleagues explain things to me because […] I do not teach science*; nevertheless, she had to *work with it [...] plan things […] well in advance and […] with great care [to] feel minimally secure*, hence constantly having to adjust her preparation. She also had to resort to textbooks for English native learners and solid online search (OBSV).

Both the English and science teachers presented the need for organizing Power Points with text, images, sound and more, as well as worksheets to help students (tEng1, *materials sometimes even playful to […] catch the students' attention [using] visuals, audios, videos*; tSci1, *in Portuguese we do not need to show the picture first for them to get the word*). Besides requiring the knowledge of English scientific terms, the non-language teachers had to be able to prepare and implement science classes speaking the FL, during a longer time and feeling more stressed than when their L1 was used (tSci1, *while projecting a PPT, I have [the sequence] in Word for myself […] to know [what] to say and ask*; tSci2, *it's a double responsibility […] to organize the pedagogical relationship and the subject education […] then the question of mastering the language, the communication, the written level, the pronunciation itself*).

Also, from the former EP students' perspective the content teacher was challenged by English being present, a condition that resulted in accurate and accessible practices to try to guarantee the learners' understanding (see Piacentini et al., 2018). A clear teaching by means of language support and greater interaction was related, so that students could overcome the difficulties encountered in having to learn concepts through English (a-*[through the teacher's] difficulties [with English] she ended up asking us how [to] conjugate that verb, say that word [producing] an interaction between teacher and student, more in English than in Portuguese*; b-*even teachers from time to time needed to use a less technical language in English [trying] to simplify as much as possible for us not to have too many difficulties*) (sINTER).

B4, Experience of learning science with/in English

The CLIL EP project was framed as an approach for English bilingual teaching (DOCS). Piacentini and Simões (2022) have already revealed the learning experience through the co-teaching and assessment strategies, the whole school community's involvement linked with the project as well as the sense of membership and responsibility that students had developed. A "composite learning[7]" has been also depicted in Piacentini et al. (2018), mainly as "learning science merely translated into English" (see B5). Our focus in this section is on the attitudes towards science from EP attenders, the majority of data resulting from current students (sQUEST).

Almost 85% of the nicknames chosen within EP had to do with (natural) science fields, astronomy (not covered by the 7th and 8th grades' NS syllabi) and petrology (part of the first-year syllabus at lower secondary school) being the most reported ones. Science-related nicknames that learners opted to use (*Kika the scientist*, *Eukariotic girl*, *Thunder kid*, *Cell-men*, *Penguin_on_ice*, etc.) show a bond with the subject and knowledge acquired. In terms of students' favourite disciplines, English (first FL) and French (second FL) scored the maximum (50 points) and minimum (5 points) absolute frequencies, respectively; Portuguese (L1) was ranked in the first quartile (12). Both physical education and mathematics equaled 34. Natural sciences and physics-chemistry were moderately chosen (19 and 25), but more by older EP graders than younger ones (14 and 19, respectively, as opposed to 5 and 6). Furthermore, 14 out of the 26 ex-EP students attended science at high school (OBSV).

The CLIL EP project also contributed to the achievement of "transversal" competences (*responsibility*; *organization, execution and evaluation of a diversity of activities*; *application of work and study methods*; *speaking […] in front of an audience*; *creative, interdisciplinary [...] and collaborative skills*) and to the learners' self-concept reinforcement, as declared in the EP report (DOCS). Within the extra-curricular activities carried out in 2015-2016, all EP groups were engaged in theatre performances connected with NS topics (OBSV), as also described by tEng1 (*small dramatizations with students, canonical texts totally rewritten by them […] they included two scientists and Camões […], the scientists*

[7] In evidence coded as such both science and English/Language were explicitly mentioned.

explained Macbeth's according to what they had learned in science). Participation in debates (such as those observed during some tSci1's classes) offered another opportunity to practice orality.

These aspects notwithstanding, difficulties embedded in being EP students were, among science learners, the most represented concern (a-*it's a very demanding and laborious project*; b-*[we] need much study time, which can lead to less time for other disciplines*; c. *we have some difficulties that do not exist in other classes*; d. *it requires of us more, hence marks decreased a little*), exceeding the language understanding referred to as an obstacle (less than 25%) (sQUEST). They also felt a higher teacher expectation (*teachers think that just because we're in the EP we have to know everything and we can't be wrong*).

B5, Scientific lexicon in English

All teachers mentioned the need for knowing English scientific vocabulary (tINTER). The concern of having science lexicon translated into English was noted within planning and classroom practices, for single technical words (*folds*, *faults*, *tensional/compressive forces*, etc. from the 7th grade science syllabus) and also for whole body systems or complex health topics (OBSV). For this, the two science teachers constantly relied on tEng1, who felt sometimes overwhelmed, as if she was a *walking dictionary*. The EP planning remarked that *the focus of classes and learning is placed on the expansion of the vocabulary area associated with subject content [or] topic* (DOCS).

Although current students acknowledged that the CLIL EP provision implied the learning of both Content (Science) and Language (English), almost 65% of the answers conveyed the learning of science in English and the acquisition of scientific terms in English (sum of 31%, "learning science in English"; 22%, "scientific English mastery"; and 11%, "increased vocabulary of both science and English") (sQUEST). This pattern matched the opinion of former EP students, who attended the project of history: 6 out of 11 explicitly alluded to a learning of both Content and Language, most of the times meaning "classes of history in English" (sINTER, see Piacentini et al., 2018).

B6, Expanded knowledge of science

All teachers agreed on the advantage of greater student proficiency in English, but also of an enhanced knowledge in the specific subject (tINTER), even though this was not explicit in the two EP documents. Instead, *mastery of the non-linguistic disciplinary content in the FL*, *motivation of students for learning the [project] non-linguistic discipline(s)* and *promotion of inter/trans-disciplinarity* as well as knowledge application and enrichment in specific educational activities linked with science (visits, cinema, etc.), were found (DOCS).

As also noted during PT classes (OBSV), teachers related that students achieve additional and alternative information (tEng1, *[during] PT […] they go deeper, have extra information and in a playful way [and] gain another type of knowledge*; tSci1, *I had never taught a class on dinosaurs [because] it's not included in the syllabus [but by doing] it in English [they] learn vocabulary [and] have contact with something scientific*) (tINTER). This is consistent with the insight into the subject shown by older students (a-*[the project] gives us a more general and comprehensive idea than the discipline itself, the textbook*; b-*we learned about a different History […] we don't have much of this range [...] at lower and secondary schools*) (sINTER) and the socio-scientific discussion encouraged during project time (OBSV).

From tSci2's perspective, the presence of English in the project enables learners to perceive science as "universal", broadening the knowledge and the vision of it (*science […] has become a resource […] for understanding the world [and] solving problems [...] by the language being present [the project] likely broadens a bit more this vision of something […] beyond the country*), as already highlighted by Piacentini and Simões (2020). EP Science students saw advances in the English language sphere as the main advantage of participating in the CLIL EP project, referring to scientific knowledge per se only in some idiosyncratic answers (*it helps us to better understand topics learnt in science*) (sQUEST).

B7a, Engaging teaching approach through alternative strategies and methods

In the final part of the EP planning, teachers wrote: *the teamwork and interdisciplinary pedagogical cooperation led to the implementation of creative and innovative teaching practices, the diversification of pedagogical methods, educational materials and of resources used in class* (DOCS). Teachers tended to develop non-conventional practices (cinema at school, game-based activities, plays, etc.) interesting for students, who learn through engagement with the activity (OBSV), as tEng1 also remarked: *nowadays we have difficulty in capturing students' attention [...] in the end the expository practice still prevails a little in many disciplines, [this approach makes] students interact, enter [...] much more in learning […] naturally, without much effort* (tINTER). In fact, the PT itself was planned as a context for developing group works–not feasible otherwise as the interview revealed–and task-based learning for science (DOCS).

One former student's narrative is significant to summarize key aspects of the adoption of a different approach by teachers to appeal to learners: *classes were much more of a dialogue and the teacher taught in a different way […] the one before the project [would] be talking and reading the textbook by herself and writing on the board*; she added that *[through] the project […] we were able to research more about this topic, we did not just hang around, we wanted to explore more* (sINTER). Furthermore, in another student's opinion, *all those activities made us learn much* *better […] it was not memorizing [for] the test […] and that's it, we worked [also] through theaters, these are things that end up staying with us.*

B7b, Engaging teaching approach through the use of a different language

The use of a rap song in English during EP science classes generated a widespread enthusiasm for learning about plate tectonics, since everybody was singing (OBSV). According to tSci1 different learning styles were encouraged, even "inverting" expectations of students' performance: *sometimes we [have] high expectations for students [with] very good marks [but] they're not very creative and others are extremely creative and do fantastic things* (tINTER). This approach also *makes science and language much more interesting, [we organized] group works on life origin [...] to show that it's [your group's] theory that is right. This in English […] generated a fabulous debate and made them shine*. Former students confirmed this difference created through using a non-L1 (a-*[with] the difference of the language, we were much more curious to study in English than in Portuguese*; b-*we [were] more attentive and more willing to learn because it was different*) (sINTER). However, participation in these strategies and activities was not always extended to all current learners (OBSV).

DISCUSSION

This work has, as a first objective, to characterize, in non-CLIL conditions, participant teachers' and students' both perceptions of science and practices (and languages) of science education. Scientific disciplines and practices are viewed, by individuals learning science or not familiar with it, with a deep trust (students of different ages), admiration (one English teacher) but also distance (the other one), conveying "ideas-about-science" to be reflected on (see Osborne, 2007). In delineating the relationship between "culture" and "science" (Martins, 2002) and addressing the relevance of school science (cf. Holbrook & Rannikmae, 2009), the vision of science as integrated into and with the general culture is predominant among students, who regard it as relevant to understanding and living in the environment, for personal development and everyday use, applying concepts and principles related to scientific activities and showing that they are important in their daily lives. The science curriculum is also deemed to be meaningful, in enabling the understanding of science topics, scientific practices (observation, experiments, etc.) and a different posture with respect to common events. The idea of a "scientific culture" emerges from those who project the learning of science for studying science at university or working in the area of science. For subject teachers, cultural and personal aspects are not irrelevant to science, since science can be linked with local and non-local people's knowledge, as also seen in Salehjee and Watts's (2020) work, and is viewed as making sense of everyday life.

Science knowledge is constructed through the "science languages", that is, a diversity of semiotic modes–spoken and written words; images, tables, diagrams, etc.; symbols and calculations; actions to make sense within experimental procedures and operations; among others–representing and communicating science concepts and processes (Bezemer & Kress, 2020; Lemke, 2003). In the science classroom, as Espinet et al. (2012) highlight, language does have a key role. Within the instrument developed by Piacentini et al. (2017) to observe and supervise the language use in/and science learning, the verbal language also entails "scaffolds" such as modulating the speech, using the first-person plural, waiting for the student to answer or developing questions gradually, which are strategies to aid the learners' science understanding not fully availed of by participant teachers. Non-verbal interventions (modulating gazes, using gestures, moving through the space, drawing, etc.) are, according to Bezemer and Kress (2020) and Cope and Kalantzis (2009), fundamental to expressing (science) meaning, and can make a difference in involving learners. Nevertheless, the systematic deployment of these strategies depends on the teaching style. On a different level, classrooms do not present visuals on the wall, for instance, summarizing plate boundaries, illustrating ecological relationships, listing body components or making equations visible. These aids do not prevent students from constructing knowledge and skills; on the contrary, the use of images and other multimodal resources ("visual thinking") can make abstract ideas conveyed in scientific formats more accessible (Fernández-Fontecha et al., 2020).

Students' difficulties with science learning identified here are also associated with obstacles in "deciphering"–to quote Lemke (2003)–the different modes used to represent it. Science activities have language demands (Seah & Silver, 2018): structuring but also understanding concept maps, for example, requires of participant students conceptual knowledge and synthesis ability; participation in debates and writing of reports mean that they must possess knowledge and use the language (oral argumentation and written organization, respectively) (see Piacentini et al., 2016). However, as already noted by Lemke (2003) and Seah and Silver (2018) in their studies, teachers expert in this subject–which they had learnt at university and have always taught–may not perceive the existence of these difficulties. The understanding of specific terminology as well as of visual information during classes, actually, seems to be taken for granted. Many scientific words are "conceptually dense" and need to be "teacher-mediated" (cf. Gajo, 2007); the teacher could have paraphrased or explained "shear" through "rock deformation due to the sliding of tectonic plates in opposite directions" and visual support (using an image, animation or drawing and also gesturing). In terms of visuals, even the "simple" water or nitrogen cycle diagram is "stuffed" with symbols having specific meanings and requires, again, a process of "undensification".

This meaning-making must be learnt, by students as much as by citizens responsible for taking decisions about socio-scientific issues who should be able, primarily, to extract and interpret information, as Holbrook and Rannikmae (2009) and Howell and Brossard (2021) maintain. To develop science knowledge, time must be devoted to the construction of science languages and communication, also because "finished science" only exists when it can be reported to a wider audience–as internalized by one teacher (Piacentini et al., 2019)–and "evaluated critically by other scientists", Osborne extends (2007, p. 180). Unfortunately, it seems that there is no space in this school learning environment for such a practice. This could be because teachers are not used to it or because they might not have trained to adopt a "language focus" in the teaching of science, and they may feel pressure for students to achieve performance goals. We understand the participant science teachers' point of view but also consider that a sensible teacher work might aim to "reduce the coverage" as alluded to by Osborne (2007), rather than to instill an encyclopedic classification of minerals, species or every single component of the digestive system, in order to "cultivate" principles underpinning the study of core sciences–i.e.: structure vs function (biology); molecular organization and macroscopic behavior (schemistry); cycles and present features vs past processes (geology)–through relating knowledge to everyday experiences and basing the learning on inquiry.

Having said that, the use of the science laboratory is a fact in Portuguese schools, with the "facilitating" factor of the teacher working with only half the class on the construction of concepts and principles through the development of practical and experimental activities (see Vieira, 2018), which allows for the practice and promotion of the kinesthetic language and intelligence (Lemke, 2003). Teachers are obviously supposed to take into account that the conditions created through a simulation of a phenomenon are different from those of an experiment, which involves variables and implies conceptual and linguistic demands. Following the "reconfigured" multimodality by Cope and Kalantzis (2009) and their inclusion of the tactile mode, we deem the use of "manipulatives" or "realia" to be suitable also within non-laboratory classes, representing opportunities for pupils to learn through a variety of styles, even in the English classroom as emerging from Piacentini et al. (2019). The presence of school projects providing a contextualization to the knowledge of science and other subjects can increase science's relevance for students, but a "project posture" (by means of problem solving and scientific inquiry) could be embedded in regular lessons rather than being performed and assessed separately, also considering that Portuguese teachers are often "busy" on different fronts.

Participant teachers and experienced students also reported English as the language often used in science and in science educational resources, more diversified in this language than in Portuguese (or any other language). Here, we must bear in mind that English is a fixture in Portuguese television and English has a role in science as the language of broadcasting (students) and of research (teachers). Piacentini et al. (2016) warn that this demands a careful discussion at school about science's nature and history, scientists' non-just-English origin and the medium of communication. We align with Salehjee and Watts (2020) in that school science should not be separated from the daily contexts with which learners have contact, and advocate the teacher's acquaintance with this background to orientate a meaningful science education (and integration with English). Contexts where learners experience science alongside English are scientific documentaries, news on television, visits during which information is shared through the language, that is, they are all spaces where the discipline is communicated, disseminated and elucidated. This is another reason to infer that the language matters in science.

In fact, science teaching is acknowledged as helping students also to master their L1 and is a context for developing the literacy activities of talking, reading, writing and doing (Pearson et al., 2010; Polias, 2016). Irrespective of the language spoken, teachers' awareness of the science language(s)[8] is not a given (Piacentini et al., 2019) but is crucial for science teaching to be orientated towards literacy practices (Seah & Silver, 2018), viewing the teacher as a "designer of learning environments" (Bezemer & Kress, 2020). Teachers are, in fact, responsible for aiding learners in the (re)construction of the language of science that, even when the L1 (here, Portuguese) is used, can be unknown like a new FL, as alerted by Wellington and Osborne (2001). Therefore, we agree with these scholars that the science teacher is a teacher of languages: visual, symbolic, operational and others besides the "obvious" verbal one. At the micro level of classroom practice, we perceive science classes as a space where an explicit focus on language can be undertaken in science

[8] We can also interpret Lemke's (2003) representational modalities (see note 1) in the sense of genres (experiments, comparisons, explanations, discussions, etc., see Polias, 2016) and relative discourse functions (exploring, reporting, categorizing, describing, evaluating, etc., Dalton-Puffer, 2011), as well as of the epistemic processes (describing, explaining, predicting, arguing, critiquing, explicating, and defining) recalled by Osborne (2007) as central features of (science) dialogic interaction.

education, as the above-mentioned instrument–with the key features for meaning making based on Mortimer and Scott's (2003) work–displays.

A second research objective focuses on the CLIL approach used in the "English Plus" project: to understand the influence of a foreign language on the science teaching and learning within the CLIL EP project. Often CLIL is characterized as an approach through which the specific content is taught with the "side effect" of a higher proficiency in the target language, at school, rather than in private language centers (e.g.: Cenoz, 2015; Coyle et al., 2010; Lasagabaster & Sierra, 2010; Dale & Tanner, 2012; Llinares et al., 2012). In the case of the EP project, the "addition" of English in the teaching and learning of the specific subject determines significant "side changes". This opens up a research context on science instructional practice that "may inform […] curriculum developers and [the] design of more efficient instructional approaches", using Duit's (2007, p. 10) words. First of all, we note that the presence of a FL and the use of it to teach and learn a discipline leads to a more aware attitude among EP teachers who work and themselves learn for the development of such provision, as Blanchard et al. (2014), Canet Pladevall and Evnitskaya (2011), Escobar Urmeneta and Evnitskaya (2014), Grandinetti et al. (2013), Piacentini et al. (2018) have already described in their empirical works.

Teachers diversify the input through multimodal support (greater use of animations, visuals and drawings, audio, etc.) in demanding settings for students, at a cognitive and organizational level. Teachers also resort to playful activities/resources to capture the learners' attention; for example, the rap song about plate boundaries had an exemplary positive reaction towards science learning among students. Faced with scarce material and the fact that textbooks and resources for English native speakers are not always adequate for CLIL students–an aspect highlighted by Lasagabaster and Sierra (2010)–, a leap of imagination is made by teachers and, as Escobar Urmeneta and Evnitskaya (2014) and Gajo (2007) mention, content is treated and worked with extra care. Having to teach using an additional language (English), science teachers show the need for knowing what to say and how to say it, alongside having pedagogical responsibilities, and notice the difficulty of learning scientific lexicon, "invisible" in non-project conditions. Similarly, to what was reported in Blanchard et al. (2014) and Grandinetti et al. (2013), the experience faced by the teacher with her/his own language difficulties, shared also with students, and the reflection on efforts required of learners seems to "break" the paradigm of knowledge transmission, forcing the innovation of practices, which can be beneficial also when the L1 is used.

Piacentini et al. (2019) refer to this useful approach as CMIL (Integrated Learning of Content while using the Mother tongue to communicate); as one high school student also pointed out, it is a matter of method regardless of the language spoken. The role that the English teacher takes on during co-taught science classes (see Piacentini & Simões, 2022) is to integrate the subject's verbal representation by means of the paraphrasing of dense terms, labeling and sketching to show meanings and associations, that is, the use of the science languages within CLIL appears enhanced, through "shifting between modes and re-representing" the same concept (Cope & Kalantzis, 2009, p. 179). Furthermore, Power Points or other formats used to present information seem to "reconfigure"–to quote again these authors–the science languages, for combining forms multi-modally. On a different level, the multimodal input typical of science education (diagrams, symbols, actions, etc.) supports understanding in a variety of manners within CLIL (Dale & Tanner, 2012; Fernández-Fontecha, 2020) and may help with planning and implementing science with a FL. A methodology is gradually built up through these circumstances of curricular integration and different competence fields deployed. As remarked by participants, this requires teacher teamwork and a collaborative environment also with students and motivates teachers to change their usual working directions and forge new learning possibilities.

The CLIL EP provision implies the learning of both science (content, C) and English (language, L) for younger learners and was indicated as "composite learning". Most of the times their description of the EP project is that it entails teaching/learning the subject while speaking another language (learning of science in English and acquisition of scientific vocabulary in English, which matches the science teacher's frequent need for having ample vocabulary translated). However, the learning of science interwoven with English is also described. This occurs in terms of teaching attention devoted to both C and L, concepts and processes of C and L learnt at the same time, and of the nature of knowledge resulting from this articulation between the FL and the specific discipline. In the older students' experience, it meant learning through the presence of English, being part of the project itself and having a rapport with learning teachers (Piacentini et al., 2018; Piacentini & Simões, 2022). Activities such as preparation of and participation in debates as well as involvement in the organization of cinema sessions or school trips are actually conceived in order to engage the student, who becomes central in the learning process. This also enables the addressing of the science education's social/affective component according to Osborne (2007).

Moreover, the presence of English, at least for former EP students, functions as a motivational factor which creates positive learning conditions. English is not necessarily more difficult, as long as initial understanding difficulties are overcome (Piacentini, 2020). We are reminded that Portuguese students are exposed every day to this FL outside of the school walls, and the "absorption of a utilitarian command of English through the new technologies" could heighten motivation to learning through CLIL, when the target language is English, as suggested by Marsh (2006, p. 35). Another consequence of the project to emphasize is the role given to strategies engaging learners orally, with the aim of promoting English use. Work presentations and participation in debates on scientific topics/ideas, being part of a play as well as working in groups with different duties are a boost for an effective use of vocabulary and the development of oral skills, and constitute crucial practices for science communication and argumentation (Espinet et al., 2012; Holbrook & Rannikmae, 2009; Osborne, 2007). Furthermore, the project time offers an additional opportunity to deepen science concepts and discuss science issues and to increase the students' effective use of English and their communicative competence.

A deeper insight into science is not an aspect of relevance that students would connect with participation in the EP project. School documents by no means present accomplishments in the learning of science as either an objective to attain or a developed competence. In defiance of these aspects, the experience of both teachers and students–who already mobilized at high school what they had learnt within EP–is that the approach adopted for the project involves a greater knowledge and a broader vision of science, and a better way to learn, as noted by Piacentini et al. (2018). On the other hand, the reference to language and cultural diversity as well as the promotion of communication skills in English and of lifelong competences (citizenship, autonomy, etc.) is recurrent in observed and spoken practices. Although some of these are essential for scientific literacy, it seems that participants do not acknowledge EP's potential for enhancing the non-English discipline, here, science education. Aligning with other CLIL authors (e.g.: Dale & Tanner, 2012; Dalton-Puffer, 2011; Llinares et al., 2012; Valdés-Sánchez, L., & Espinet, 2020), we perceive a CLIL environment as subject classes (rather than English classes on science topics), where the science teacher herself/himself can plan, implement and change practices through an explicit language focus in (science) education, like the examples of Meyer et al. (2018) or Piacentini et al. (2017) reveal.

Regarding high school options, it is worth pointing out that the science area was chosen by more than half of the ex-EP students, whereas it only had an average position in current students' ranking of their favorite subjects. Different reasons can be considered to explain this, such as the teacher whom they had or that changes occurred in their minds, but it might be an effect of having learnt through a "method" determining a different disposition towards science. We would like to remark that 8th grade students, with a longer exposure to EP science, preferred both physics-chemistry and natural sciences (three times) more than 7th graders. This aspect obviously requires more data (teaching method, syllabus, etc.) to be understood, but suggests that learning through the project could offer a positive experience with science, also to those students who will not continue it after the 9th grade. On the other hand, science education within "English Plus" could be seen as a space for students to get "closer" to local cultures through offering a link with international perspectives, as Dale and Tanner (2012) indicate, with a sort of "glocal" process (that one teacher seems to suggest), which could diminish the "practice" of conflating English-speaking scientists with English-speaking countries.

CONCLUSIONS

Our study attempts to understand different aspects of science education within "normal" conditions as well as qualitative effects of the integration of English into science learning through the CLIL EP project settings, beyond the interest in English improvement. It is apparent from this research that, due to the explicit presence of language (the FL), a CLIL environment makes teachers become aware of the difficulties that students have to confront in learning science through an additional language; they thus resort to alternative and interesting resources and develop practices more centred on learners. In other words, they learn to teach better and, in doing so, they may gain the lens to perceive the existence of the science languages, at least in terms of lexicon density, potential of and need for visualization as well as discourse construction in different processes. CLIL seems to be a method-driving context which opens up the possibility for teachers to develop a language-focused science education and for researchers to reflect on and orientate teaching methodologies in this sense[9]. Therefore, CLIL underpinnings and implications could be beneficial for, and integrated into, the subject-specific education also when teachers and students are working with their L1, that is, a CMIL approach/context may be crucial to revise science educational practices, through teaching in the languages of science as much as how to use them.

Our doctoral research was not a longitudinal study, but it encompassed actors with different educational roles and participating at different times of the EP implementation. Considerations about science

[9] Piacentini (2021) considers that teaching methodologies orientated as "SCIL" (Science Constructed through the Integration of its Languages) can contribute to the development of scientific literacy.

education and the integration of English that we have just drawn may be limited to the specificity of this CLIL school project and the relatively limited number of EP groups of students and their teachers involved in the inquiry. However, empirical regularities associated with our case might be generalized to other populations that share features, such as a suitable school organization and similar instructional levels. Descriptions/interpretations of the EP phenomenon might inform those schools interested in the CLIL approach.

Further research is needed to characterize the suitability (or sustainability) of English as a language and strategy/method to scaffold science learning. To aid the development of scientific literacy, a more focused observation of how knowledge construction is linked with language progression during science classes (with L1 or FL being spoken) is also required. Studying the relationship between investigation into CLIL science with English and that on science education for English learners (in English native countries) also demands further endeavour. It will be also pivotal to continue researching with participant teachers to understand if substantial practice changes, especially in terms of representational choices and language awareness in the (single) teaching of science concepts and processes, may occur because of teaching and learning within the CLIL approach. In relation to learners, new former students (those who complete the three-year EP of science) might be excellent informants about the learning of science through English and the project. It could also be interesting to understand how the participation in the project might affect the learners' attitude towards science education and science in general and future choices in this area.

The present work contributes to extending research on CLIL science practice at a macro international level, in the sense of both integration of science education with the learning of English (as a FL) and the Language focus for science education (when using L1). At the meso level of school and teacher subject plans (and, for reflection, assessment), we consider the exploration of national regulative documents and of textbooks to be important in order to identify concepts and contexts enabling a "natural" educational articulation with English and the cultivation of the science languages (verbal in L1/FL and other modes). Regarding the micro learning environment under study, the understanding of how knowledge and learning of science might be enhanced by English being present could move CLIL research forward and contributes to that on science education, "beyond [what is thought so far of] CLIL[10]", preparing teachers to put science and English "each in service of the other[11]".

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REFERENCES

Bezemer, J., & Kress, G. (2020). Semiotic work in the science classroom. *Cultural Studies of Science Education, 15*(1), 71-74. https://doi.org/10.1007/s11422-019-09957-4

Blanchard, B., Masserot, V., & Holbrook, J. (2014). The PROFILES project promoting science teaching in a foreign language. *Science Education International*, *25*(2), 78-96. https://eric.ed.gov/?id=EJ1032970

Bruton, A. (2013). CLIL: Some of the reasons why… and why not. *System*, *41*(3), 587-597. https://doi.org/10.1016/j.system.2013.07.001

Canet Pladevall, R., & Evnitskaya, N. (2011). Rethink, rewrite, remake, or learning to teach science through English. In C. Escobar Urmeneta, N. Evnitskaya, E. Moore, & A. Patiño (Eds.), *AICLE-CLIL-EMILE: Educació plurilingüe. Experiencias, research & polítiques* [*Multilingual education. Experiences, research & policies*] (pp. 167-177). Servei de Publicacions de la Universitat Autònoma de Barcelona.

Cenoz, J. (2015). Content-based instruction and content and language integrated learning: The same or different? *Language, Culture and Curriculum*, *28*(1), 8-24. https://doi.org/10.1080/07908318.2014.1000922

Cope, B., & Kalantzis, M. (2009). "Multiliteracies": New literacies, new learning. *Pedagogies: An International Journal, 4*(3), 164-195. https://doi.org/10.1080/15544800903076044

Coyle, D., Hood, P., & Marsh, D. (2010). *CLIL Content and Language Integrated Learning*. Cambridge University Press. https://doi.org/10.1017/9781009024549

Coyle, D., & Meyer, O. (2021). *Beyond CLIL. Pluriliteracies teaching for deeper learning*. Cambridge University Press. https://doi.org/10.1017/9781108914505

[10] Inspired in part by Coyle and Meyer's book "Beyond CLIL. Pluriliteracies Teaching for Deeper Learning" published in 2021.
[11] Inspired by Pearson et al.'s (2010) work.

Dale, L., & Tanner, R. (2012). *CLIL activities. A resource for subject and language teachers*. Cambridge University Press.

Dalton-Puffer, C. (2011). Content-and-Language Integrated Learning: From practice to principles? *Annual Review of Applied Linguistics*, *31*, 182-204. https://doi.org/10.1017/S0267190511000092

Duit, R. (2007). Science education research internationally: Conceptions, research methods, domains of research. *Eurasia Journal of Mathematics, Science & Technology Education*, *3*(1), 3-15. https://doi.org/10.12973/ejmste/75369

Ellison, M. (2018). (Net)working CLIL in Portugal. *E-TEALS*, *9*(s1), 4-22. https://doi.org/10.2478/eteals-2018-0010

Escobar Urmeneta, C., & Evnitskaya, N. (2014). 'Do you know Actimel?' The adaptive nature of dialogic teacher-led discussions in the CLIL science classroom: A case study. *The Language Learning Journal*, *42*(2), 165-180. https://doi.org/10.1080/09571736.2014.889507

Espinet, M., Izquierdo, M., Bonil, J., & Ramos-de Robles, S. L. (2012). The role of language in modeling the natural world: Perspectives in science education. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (pp. 1385-1403). Springer. https://doi.org/10.1007/978-1-4020-9041-7_89

European Commission. (2003). *Promoting language learning and linguistic diversity: An action plan 2004 - 2006*. European Communities.

European Commission. (2017). *Key data on teaching languages at school in Europe–2017*. Education, Audiovisual and Culture Executive Agency. https://data.europa.eu/doi/10.2797/04255

Fernández-Fontecha, A., O'Halloran, K. L., Wignell, P., & Tan, S. (2020). Scaffolding CLIL in the science classroom via visual thinking: A systemic functional multimodal approach. *Linguistics and Education*, *55*, 1-10. https://doi.org/10.1016/j.linged.2019.100788

Fernández-Sanjurjo, F., Fernández-Costales, A., & Arias Blanco, J. M. (2019). Analysing students' content-learning in science in CLIL vs. non-CLIL programmes: Empirical evidence from Spain. *International Journal of Bilingual Education and Bilingualism*, *22*(6), 661-674. https://doi.org/10.1080/13670050.2017.1294142

Gajo, L. (2007). Linguistic knowledge and subject knowledge: How does bilingualism contribute to subject development? *International Journal of Bilingual Education and Bilingualism*, *10*(5), 563-581. https://doi.org/10.2167/beb460.0

Gimeno, A., Seiz, R., de Siqueira, J. M., & Martínez, A. (2010). Content and language integrated learning in higher technical education using the *inGenio* online multimedia authoring tool. *Procedia-Social and Behavioral Sciences*, *2*(2010), 3170-3174. https://doi.org/10.1016/j.sbspro.2010.03.484

Grandinetti, M., Langellotti, M., & Ting, Y.-L. T. (2013). How CLIL can provide a pragmatic means to renovate science education–even in a sub-optimally bilingual context. *International Journal of Bilingual Education and Bilingualism*, *16*(3), 354-374. https://doi.org/10.1080/13670050.2013.777390

Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental & Science Education*, *4*(3), 275-288. http://www.ijese.net/makale/1394

Howell, E. L., & Brossard, D. (2021). (Mis)informed about what? What it means to be a science-literate citizen in a digital world. *Proceedings of the National Academy of Sciences*, *118*(15), 1-8. https://doi.org/10.1073/pnas.1912436117

Lasagabaster, D., & Sierra, J. M. (2010). Immersion and CLIL in English: More differences than similarities. *ELT Journal*, *64*(4), 367-375. https://doi.org/10.1093/elt/ccp082

Lemke, J. (2003). *Teaching all the languages of science: Words, symbols, images, and actions*. http://www.jaylemke.com/science-education/

Llinares, A., Morton, T., & Whittaker, R. (2012). *The role of language in CLIL*. Cambridge University Press.

Marsh, D, Mehisto, P., Wolff, D., & Frigols Martín, M. J. (2011). *European framework for CLIL teacher education*. European Centre for Modern Languages.

Marsh, D. (2006). English as medium of instruction in the new global linguistic order: Global characteristics, local consequences. In *Proceedings of the 2nd Annual Conference for Middle East Teachers of Science, Mathematics and Computing* (pp. 29-38). METSMaC.

Martins, I. P. (2002). *Educação e Educação em Ciências* [*Education and science education*]. Universidade de Aveiro.

Mehisto, P. (2012). Criteria for producing CLIL learning material. *Encuentro*, *21*, 15-33. http://files.eric.ed.gov/fulltext/ED539729.pdf

Merriam, S. B. (1995). What can you tell from a N of 1? Issues of validity and reliability in qualitative research. *PAACE Journal of Lifelong Learning*, *4*, 51-60. https://ethnographyworkshop.files.wordpress.com/2014/11/merriam-1995-what-can-you-tell-from-an-n-of-1-issues-of-validity-and-reliability-in-qualitative-research-paace-journal-of-lifelong-le.pdf

Meyer, O., Coyle, D., Imhof, M., & Connolly, T. (2018). Beyond CLIL: Fostering student and teacher engagement for personal growth and deeper learning. In J. D. Martínez Agudo (Ed.), *Emotions in second language teaching* (pp. 277-297). Springer. https://doi.org/10.1007/978-3-319-75438-3_16

Meyerhöffer, N., & Dreesmann, D. C. (2019). The exclusive language of science? Comparing knowledge gains and motivation in English-bilingual biology lessons between non-selected and preselected classes. *International Journal of Science Education, 41*(1), 1-20. https://doi.org/10.1080/09500693.2018.1529446

Mortimer, E. F., & Scott, P. H. (2003). *Meaning making in secondary science classrooms*. Open University Press.

Osborne, J. (2007). Science education for the twenty first century. *Eurasia Journal of Mathematics, Science & Technology Education, 3*(3), 173-184. https://doi.org/10.12973/ejmste/75369

Pavón Vásquez, V., & Ellison, M. (2013). Examining teacher roles and competences in Content and Language Integrated Learning (CLIL). *Lingvarvm Arena, 4*, 65-78. http://193.137.34.194/index.php/LinguarumArena/article/viewFile/3967/3715

Pearson, P. D., Moje, E., & Greenleaf, C. (2010). Literacy and science: Each in the service of the other. *Science, 328*, 459-463. https://doi.org/10.1126/science.1182595

Piacentini, V. (2020). *Science education and the integration of English for learning: Study of one CLIL approach in a Portuguese lower secondary school* [Unpublished doctoral dissertation]. University of Aveiro. http://hdl.handle.net/10773/28939

Piacentini, V. (2021). CLIL and Science education. A review for a Language focus in Science teaching. *Ricerche di Pedagogia e Didattica – Journal of Theories and Research in Education, 16*(3), 113-131. https://doi.org/10.6092/issn.1970-2221/12646

Piacentini, V., & Simões, A. R. (2020). CLIL: A way to develop plurilingual and intercultural competences in schools? In F. Anastassiou & G. Andreou (Eds.), *English as a foreign language: Perspectives on teaching, multilingualism and interculturalism* (pp. 54-83). Cambridge Scholars Publishing.

Piacentini, V., & Simões, A. R. (2022). Teaching and learning in the Portuguese "English Plus" project. In M. Ellison, M. Morgado, & M. Coelho (Eds.), *Contexts and conditions for successful CLIL in Portugal* (in press). U. Porto Press.

Piacentini, V., Simões, A. R., & Vieira, R. M. (2016). Abordagem holística no sistema educativo português para desenvolver a(s) Literacia(s) das Ciências integradas com o Inglês [Holistic approach in the Portuguese education system to develop literacies of science integrated with English]. *Indagatio Didactica, 8*(1), 1975–1992. https://doi.org/10.34624/id.v8i1.12417

Piacentini, V., Simões, A. R., & Vieira, R. M. (2017). The language focus of science education integrated with English learning. *Enseñanza de Las Ciencias, Extra*(2017), 399-404. https://ddd.uab.cat/record/184622

Piacentini, V., Simões, A. R., & Vieira, R. M. (2018). What students tell teachers about practices that integrate Subjects with English in a lower secondary school in Portugal. *e-TEALS, 9*(s1), 57-76. https://doi.org/10.2478/eteals-2018-0013

Piacentini, V., Simões, A. R., & Vieira, R. M. (2019). Teachers' view of Language(s) in (CLIL) Science education: A case study in Portugal. *Problems of Education in the 21st Century, 77*(5), 636-649. https://doi.org/10.33225/pec/19.77.636

Polias, J. (2016). *Apprenticing students into science: Doing, talking, and writing scientifically*. Lexis Education.

Roberts, D. A., & Bybee, R. W. (2014). Scientific literacy, science literacy, and science education. In N. G. Lederman, & S. K. Abell (Eds.), *Handbook of research on science education volume II* (pp. 545-558). Routledge.

Salehjee, S., & Watts, M. (2020). *Becoming scientific: Developing science across the life-course*. Cambridge Scholars Publishing.

Seah, L. H., & Silver, R. E. (2018). Attending to science language demands in multilingual classrooms: A case study. *International Journal of Science Education, 42*(14), 2453-2471. https://doi.org/10.1080/09500693.2018.1504177

Simões, A. R., Pinho, S. A., Costa, M. A., & Costa, R. A. (2013). The Project English Plus: A CLIL approach in a Portuguese school. *Indagatio Didatica, 5*(4), 30-51. https://doi.org/10.34624/id.v5i4.4280

Stake, R. E. (1994). Case studies. In N. K. Denzin, & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp. 236-247). SAGE.

Valdés-Sánchez, L., & Espinet, M. (2020). Coteaching in a science-CLIL classroom: Changes in discursive interaction as evidence of an English teacher's science-CLIL professional identity development. *International Journal of Science Education, 42*(14), 2426-2452. https://doi.org/10.1080/09500693.2019.1710873

Vieira, R. M. (2018). Didática das ciências para o ensino básico [*Science teaching methods for primary school levels*]. Sílabas & Desafios.

Wellington, J., & Osborne, J. (2001). *Language and literacy in science education*. Open University Press.

Wolff, D. (2012). The European framework for CLIL teacher education. *Synergies Italie*, (8), 105-116. http://gerflint.fr/Base/Italie8/dieter_wolff.pdf

Yin, R. K. (1994). *Case study research. Designs and methods*. SAGE.

APPENDIX A

Teacher Interview Guides (EN, English; SCI, Science)

1	What is your time of service as a school teacher? EN–Briefly, what is your education path to becoming a teacher of English? SCI–Briefly, what is your education path to becoming a science teacher? Have you ever collaborated with teachers of other areas? How did it go?
2	EN–Can you describe your science learning experience at school? SCI–Can you describe your learning experience with foreign languages? EN–How do you think you use this knowledge in your daily life? SCI–What about their use (informal communication, higher education, at work, etc.)?
3	What is your position/opinion about the statement? “Science teacher is a language teacher”?
4	Can you talk about examples in the planning and implementation of your classes? that allowed you to make curricular/scientific concepts and topics understandable for your students?
5	How important do you consider students’ participation in class? How do you promote it in your English/science classes?
6	EN–What role do you attribute to problem-solving, questioning, and argumentation in learning of English at school? SCI–How would you describe the role of hands-on and experimental activities in learning of science at school? EN–And to hands-on and experimental activities? SCI–And of questioning and argumentation? EN–And to collaboration? SCI–And of collaboration?
7	EN–Do you think that learning English can promote plurilingualism? How? SCI–Do you agree with the idea that scientific knowledge is constructed? How?
8	EN–How can the cultural dimension be worked on in Language classes? SCI–How do you think that culture(s) can be deepened in Science classes?
9	What connections can you highlight between Science education and the practice of English?
10	Can you share what you know about CLIL, the approach of the “English Plus” project? Do you think you have already implemented classes, or partly, through this approach?
11	What responsibilities (in planning and implementation) do you think that a teacher has as a CLIL teacher?
12	How do you imagine that CLIL classes integrate the 4Cs (Content knowledge; Cognitive processes implied; Communicative contexts; Cultural aspects) suggested in reference texts? How do you think CLIL can promote language and science learning?
13	How do you consider the assessment of CLIL units?
14	What needs (such as organization and education) do you think that a teacher has as a CLIL teacher?
15	Do you have expectations from this approach in terms of (professional and personal) benefits? And concerns?
16	Do you believe that this approach entails an “overload”? In what sense?
17	For you, what is CLIL’s position/distance in relation to the linguistic and non-linguistic discipline (in our case, science)?
18	Do you have ideas to add or questions to ask?

APPENDIX B

Former Student Interview Guide

1	I would like you to express your opinion about the "English Plus" project of history (organization, constraints, challenges, and advantages).
2	Did you have difficulties during the project? If yes, what were they? How did you manage to overcome them?
3	Which subject has benefited the most (in terms of structuring and understanding, communication possibilities, and integration with reality) from the project? Why? And now that you are in high school?
4	Do you think there was a difference between the classes where the history and English teachers were together and those where there was only the history one (the way teacher presented and treated the subject)?
5	Do you remember any situation in which the use of English facilitated your learning compared to Portuguese?
6	Would you like to, or do you know other languages? Which ones?
7	Do you think that English (the fact of learning/using this language) awoke your curiosity about studying/learning other languages and cultures? How?
8	Do you consider that the project has facilitated the study of scientific disciplines? If yes, how?
9	What suggestions can you give to the young students who are now involved in the EP of natural sciences

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