Universidad Internacional de La Rioja
Facultad de Educación

Trabajo fin de máster

Combining PBL and CLIL in the scientific laboratory in secondary education

Presentado por: Beatriz Álvarez Sánchez
Tipo de TFM: Research proposal MD on Bilingual Education
Director/a: Hanane Benali

Ciudad: Madrid
Fecha: 26 de Febrero de 2016

Combining PBL and CLIL in the scientific laboratory in secondary education

Abstract

Several connections can be made between the principles of CLIL methodology and the practical dimension of lab experiments. Thus, science lab offers a unique scenario for learning by doing, active learning, collaborative tasks and language use in a real context. In addition, the scientific laboratory represents a very flexible learning environment with regards to the activities that can be performed although there are no precedents of applying CLIL in lab experiments. In this research proposal, different approaches such as *project-based learning (PBL), inquiry-based learning (IBL)*, or *task-based learning (TBL),* have been used in the implementation of CLIL in the scientific laboratory for learning purposes. As a result, we propose PBL as a feasible approach to implement CLIL in the scientific laboratory as it provides the learning by doing dimension while introducing inquiry and problem solving in cognitively demanding tasks. With this aim, a methodology for effective planning PBL from a CLIL perspective is here proposed. This planning has been developed from a practical point of view, considering aspects related to lab work (*i.e.* safety considerations), CLIL methodology (*i.e.* using the 4Cs framework as a starting point to integrate language and content from a holistic view) and defining aspects of PBL (*i.e.* the creation of artifacts as a creative culmination of the project, or the generation of a driving question as the guiding force of projects).

After outlining the main aspects of CLIL-based PBL applied to scientific experiments, the expected outcomes and possible pitfalls have also been considered. The integration of project-based learning and CLIL in the scientific laboratory is expected to connect with students' needs and interests through their active role in the learning process and the real world connection of scientific projects. In addition, it should engage them in cognitively demanding tasks, while using the language in a purposeful and meaningful context, thus impacting in their lifelong learning.

Keywords

Project-based learning; PBL; Science teaching; Content and language integrated learning; CLIL and science laboratory.

Table of Contents

List of figure and tables

1. Introduction

Content and Language Integrated Learning (CLIL) is the accepted term for the practice of combining the learning of academic content with the learning and use of an additional language (Cenoz, 2015). In CLIL lessons, learners gain knowledge of the curricular subject while simultaneously learning and using the target language. One of the main pillars for content and language integrated learning (CLIL) is that languages are best learned from meaningful content in a context (Snow, Met & Genesee, 1989), what is to say, when they are contextualized and focused on the real needs of students, as communicative skills are acquired by purposeful communication. According to Cummins (1983) context is fundamental to support children's language and literacy development. In this sense, the practical dimension of laboratory sessions offers unique opportunities to learn language in an authentic environment. In fact, learning science by lab experiments involves developing knowledge and understanding of the physical world, the practical aspects of scientific concepts, and the application of scientific enquiry, while acquiring and using the scientific language.

1.1. Justification of the research question and problem

Several connections can be made between the principles of CLIL methodology and the practical dimension of lab experiments. On the one hand, science lab offers a unique scenario for learning by doing, since students are involved in active learning. It also represents a good opportunity for collaborative learning, as it is usually carried out in groups. Moreover, the scientific laboratory allows the development of language skills and the use of scientific vocabulary. In fact, in lab experiments, students are engaged in an inquiry process, while developing cognitive skills necessary to take measurements, collect and process data, describe results, conclusions and evaluate the results. Furthermore, the scientific laboratory is a unique scenario to use the language in a variety of situations, such as to cooperate with peers to distribute tasks, to discuss the results or negotiate the meaning, read a recipe or an experimental protocol in the target language or write a final report, not to forget the importance of using scientific vocabulary in the appropriate context.

Applying tasks or projects to the lab open up a wide range of possibilities. In fact, the scientific laboratory represents a very flexible learning environment with regards to the activities that can be performed. In principle, there are no limitations on the age of the students or time of the school year in which the CLIL module is conducted, as long as there is a plethora of topics and experiments that can be carried out with students from primary to secondary school. In many cases, the activity can be adapted to the school facilities or students' level, so that it is possible to perform experimental activities in the school lab, if available, as well as simple experiments in class or in the computer lab, since many simulations are now available.

1.2. Brief analysis of the state-of-the-art

The use of the scientific laboratory as a setting for CLIL lessons has been acknowledged, but scarcely explored (Tibaldi, 2012). There are also precedents of using task-based activities to activate cognitive skills in science teaching with positives results. In a research carried out by Escobar and Sanchez (2009), students improved significantly in the use of better lexical repertoire and improved fluency in the context of science academic learning in the foreign language. There are also studies that demonstrate that using CLIL in science subjects improves language awareness of students and is positively considered by students and teachers (Grant, 2009). However, there are no precedents of using CLIL in laboratory sessions for teaching purposes, despite of being the scientific laboratory represents a powerful scenario to apply CLIL in science teaching, where learn and apply the second language.

Different approaches can be used for the implementation of CLIL in the scientific laboratory for learning purposes, since CLIL can be associated to other methodological approaches such as *project-based learning* (PBL), *inquiry-based learning* (IBL), or *task-based learning* (TBL) (Tibaldi, 2012), all of them associated with "learning by doing". The best choice depends on practical aspects that should be valued beforehand but, in general, it should allow fostering creativity and autonomy of students with an effective planning and guidance from the part of the teacher (Dalton & Sison, 1995).

In this context, project-based learning (PBL) can be selected as a valid approach for the implementation of CLIL in laboratory experiments, as CLIL and PBL share many common aspects, among them: (i) the promotion of critical thinking, which appears to be essential for language and content acquisition, (ii) fostering creativity and autonomy of students, (iii) collaborative learning, (iv) extensive use of the language, (v) cater different learning styles and multiple intelligences. For an effective planning of experimental sessions following a PBL approach, it can be worth using a backward approach as proposed by Ravitz, Mergendoller, Markham, Thorsen, Rice, Snelson, & Reberry (2004), where the expected result is planned at the beginning and the project is anchored to a problem to be solved throughout a driving question. Some defining aspects of CLIL methodology must also be considered in project planning, such as the 4Cs framework (Coyle, 2007), the progression of cognition skills according to Bloom's Taxonomy (Krathwohl, 2002), and the language triptych (Coyle, Hood & Marsh, 2010) applied to science teaching.

1.3. Aims

Here we propose a research on the possibility of applying CLIL methodology to laboratory sessions, with the aim of having students actively learning through experience, making use of scientific concepts and their cognitive skills by the means of a second language. Therefore, the aim of this Research Proposal is to discuss the main points to consider to successfully integrating CLIL methodology with laboratory practice, and the potential benefits and challenges of this integration.

The research is based on the hypothesis that CLIL would benefit from the application of scientific knowledge to real contexts as part of meaningful learning experiences and "learning by doing", which is the basis of the scientific laboratory for teaching purposes. As a result, students should be able to develop cognition at higher levels, which has also been stated as a basis for CLIL learning (Coyle, 2007).

1.4. Methodology

The methodology used in this research proposal is a theoretical approach, based on the qualitative review and analysis of documents reported in bibliography on the implementation of CLIL in scientific projects. The main points to consider for an effective planning of CLIL-based experimental projects are studied and the potential benefits of this implementation are discussed.

2. Literature review

The integration of CLIL methodology in science subjects is not new. Escobar and Sánchez (2009) showed positive results on the progress in language in terms of fluency and lexical repertoire when applying CLIL to a science lesson. In addition, CLIL does not either provoke any noticeable impairment with regard to content acquisition in science learning in a CLIL-based approach, as reported by Gregorczyk (2012). This integration is based on the fact that in CLIL-based science teaching, "students learn on the physical world, the impact of science on life and the environment, scientific concepts, scientific enquiry, in addition develop the accurate use of scientific language and improve their communicative skills in the target language" (Cambridge, 2011, p.13). When considering using CLIL methodology in science subjects, we might regard the particular features of science as a subject. The Committee on Science learning (2007) defines the following strands of science education (p. 37):

1. *Know, use and interpret scientific explanations of the natural world*. This encompasses integrate many types of knowledge, including scientific ideas and their relationships as the basis to predict other natural phenomena and apply to scientific events.
2. *Generate and evaluate scientific evidence and explanations*, which implies acquiring skills and knowledge to analyze empirical evidences to be able to construct and defend explanations.
3. *Understand the nature and development of scientific knowledge,* recognizing uncertainty as part of the scientific development. Students should understand that science is continuously evolving and new evidences might led to new models, and that this should not call into question the validity of scientific arguments.
4. *Participate productively in scientific practices and discourse,* recognizing science as valuable and interesting to increase students' motivation toward science. This involves being critical and curious about scientific questions and being able to participate in scientific debates.

As a common thread in science, all the basic principles are based on experimental facts, thus, students must find the connection between the content and the application to a natural phenomenon, what is to say, science can be found out of the classroom, so the students should have the opportunity to experiment with the theoretical concepts in authentic (or simulated) environment. Developing lab experiments may offer valuable opportunities for learning the language in authentic and meaningful activities. In these types of experiments, students are expected to become the centre of the teaching/learning process, in contrast to traditional teaching styles where students are mere recipients of knowledge. In a research by Yassin, Tek, Alimon, Baharom & Ying (2010) carried out in 9 classes with different teachers it was observed that the progression of the class rely on teachers talk, in detriment to the richness of vocabulary used by the students who usually limited to answer with short sentences to the questions posed by teachers. This traditional approach tends to regard science subjects as a collection of facts rather than a range of tools to solve empirical problems. The majority of questions posed during the study were categorized at the lower cognitive taxonomic elements (i.e., remember and understand) of Blooms revised taxonomy (Khrathwohl, 2002). Lab experiments are more in agreement with current educational trends (including CLIL methodology) where students take a great deal of responsibility on their learning. In fact, we might expect the following outcomes of the integration of language and content in laboratory sessions:

- Experimental learning and hands-on experience might help students to learn by doing.

- The lab environment provides learners with authentic learning settings (e.g. doing a science experiment using lab equipment and chemical substances).
- It allows the development of cognitive skills, as it is based on *problem solving*, which might support the use of learner strategies at different levels, for instance, to formulate an hypothesis, to make use of the tools available in the lab to plan and develop an experiment, to extract factual information, to analyze data, to generate results, to extract conclusions, or to create a report;
- As they are usually carried out in groups, lab experiments represent a means for collaborative learning.
- It enables students to learn skills that they can transfer and use in other similar contexts (e.g. know-how skills to complete tasks and solve problems which involve cognitive skills) and practical skills (e.g. employment of manual skills and methods, materials, tools and instruments).
- It is through language, communication, and real life contextualization of chemistry that we will make chemistry meaningful to students.
- Laboratory activities can be performed at different school levels and anytime during the school year, as long as the activity is adapted to the language and content levels of the students.

One of the main issues in implementing CLIL to lab experiments is to choose the teaching approach that fits the best to our purpose. Although this will depend on factors such as the topic, the age of the students and their prior knowledge or safety considerations, which might vary from one experiment to another, we can find different possibilities that could be worth exploring before designing the CLIL experiment. The most extended approaches in laboratory sessions for learning purposes are based on task-based learning (TBL), project-based learning (PBL), and inquiry problem solving or inquiry-based learning (IL).

2.1. Approaches in CLIL-based laboratory

Throughout the history of chemistry education different styles of laboratory instruction have been prevalent: expository, inquiry, discovery, and problem-based (Domin, 1999). For expository lessons (also known as task-based learning), both the students and the teacher know the final result of the experimental research. For problem-based activities (or by extension, for project-based learning), usually it is only the teacher who knows the expected result. On the other hand, inquiry-based learning require the students to device the learning process by formulating the problem, predict the result, identify the procedure, and perform the investigation. These types of laboratory instruction are here outlined and compared.

2.1.1. Task-based learning

The Common European Framework of Reference for Languages (CEFR) defines a task, cited by Tardieu and Doliksky (2012):

> As any purposeful action considered by an individual as necessary in order to achieve a given result in the context of a problem to be solved, an obligation to fulfill or an objective to be achieved. This definition would cover a wide range of actions such as moving a wardrobe, writing a book, obtaining certain conditions in the negotiation of a contract, playing a game of cards, ordering a meal in a restaurant, translating a foreign language text or preparing a class newspaper through group work (p.9).

Task-based learning (TBL) is characterized by the following common features (Escobar & Sánchez, 2009):

- The importance of meaning over form. This criterion is, per se, constitutive of a CLIL classroom. Language is the mean to do the task, not the end.
- There is a final goal to achieve: goals should be concretely established, and they must be easily identifiable for learners.
- The activity is evaluated according to the achievement of the final results: This is the level of efficacy in the resolution of a particular problem, in the communication of a message to a peer or to the rest of the class, which determines the level of achievement in the task.
- There is a real-world relationship: The connection with experimental facts outside the lab should be stated and identified by students.

Although the term task is wide, we can assert, from a CLIL-oriented point of view, that tasks involves a progression from low high order thinking skills, promotes students interaction in an authentic or simulated environment, and students towards reaching an end to the task but the importance is given to the learning process over the final results of the task. In tasks, the outcome is well defined and teacher acts as a facilitator, but students should be prompted to work on their own, by autonomous learning.

From the point of view of lab-based science teaching, TBL fits with expository instruction, which is the most common, and also most criticized style of laboratory instruction (Domin, 1999). In TBL, experiments can be planned as tasks, where students have to follow a protocol to reach an end, which is well defined. Thus, students are not expected to carry out investigations by themselves, as there is not an inquiry process. Nevertheless, tasks are valuable in laboratory experiments as they respect the "learn by doing" dimension of experimental work.

2.1.2. Inquiry problem solving

Inquiry problem solving or Inquiry Learning (IL) has been acknowledge as a valuable style for science learning (Tracy & Abd-Hamid, 2006):

> Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanation*s* (National Research Council, 1996, p. 23).

Well-designed, inquiry-type laboratory activities can provide learning opportunities to develop high-level learning skills. In a learning environment, investigation involves to construct scientific assertions, and to justify those assertions in a classroom community of peers. In IL, students are encouraged to play with variables and hypothesize, and the result of the experiments might be unpredictable. In this sense an inquiry-based approach is student-centered, offering situations to promote critical thinking skills at higher cognitive levels more than in traditional teacher-centered science teaching.

In inquiry-based learning, teachers' role is left in a second place, so that students drive the pace of the learning with their own reasoning. Teacher, on the other hand, can act as a guide using the correct questions inquiring why, asking to explain facts or to establish connections. Thus, the development of the activity is open-ended, giving freedom to students to learn at their own pace.

As demonstrated by Dalton & Sison (1995), content and language learning can benefit one from the other in an inquiry-based approach. This can be due to a progression from concrete strategies to abstract reasoning, which requires more complex linguistic skills. In fact, there are a variety of strategies needed in an inquiry based approach, such as ask for repetition, reflect on ideas, infer, understand processes, participate in discussions, share results, express opinions, draw conclusions or summarize. Aspects of inquiry—such as discourse; questioning; investigating; observing, classifying and measuring objects and phenomena; and collecting and analyzing data—can create an environment favorable to second- language development (Laplante, 1997).

Although IL has been acknowledged to cognitively engage students, their effectiveness has been questioned (Novak & Linn, 1977) by those who argue that IL is a type of minimally guided instruction, which fails against direct instructional guidance. In the case of science learning, students can get frustrated and confused in pure discovery methods and lead to misconceptions, while student learn more deeply in strongly guided learning. In fact, in IL, students can get overwhelmed by too much demand on their short-term memory by requiring students to simultaneously attend to new subject matter concepts, unfamiliar laboratory equipment, and novel problem-solving tasks (Domin, 1999)

2.1.3. Project-based learning

According to Thomas (2000), project-based learning (PBL) is:

> A teaching model that organizes learning around projects, which are complex tasks, based on challenging questions or problems, that involve students in design, problem-solving, decision making, or investigative activities; give students the opportunity to work relatively autonomously over extended periods of time; and culminate in realistic products or presentations (p. 1).

Thus, students are perceived as agents of their own learning. In terms of cognition, it means that they are responsible of problem-solving, decision making and creating. In a PBL approach, students are engaged in a collaborative real-world investigation, where knowledge, thinking and doing are inextricably tied (Universidad Internacional de La Rioja, 2015).

Some of the defining features of PBL are (Thomas, 2000):

- PBL are central to the curriculum, students learn the central concepts of the discipline by means of the project. Thus, projects aiming at providing examples, practical applications or additional practices cannot be considered as PBL.
- PBLs are designed around a driving question anchored to a real-world problem that helps students to make connections between the activities to the underlying conceptual knowledge. In order to approach to this question, students must carry out a variety of tasks in an extended inquiry process, for which they will need to learn and apply content-related concepts, collaborate with students and teachers and represent the final product using technology.
- Students are involved in a constructive investigation, which is a goal-oriented process that requires inquiry, knowledge building and resolution. If the project

represents no difficulty to the student or can be carried out with the application of already-learned information or skills, the project is an exercise, not a PBL.

- Projects are, in essence, student-driven. Thus, understanding occurs when a learner actively constructs meaning based on his or her experiences and interaction in the world and that only superficial learning occurs when learners passively take in information transmitted from the teacher. PBL projects incorporate a good deal more student autonomy, and unsupervised work time, and responsibility than traditional instruction. By this means, learners actively build knowledge as they explore the surrounding world, observe and interact with phenomena, take in new ideas, make connections between new and old ideas, and discuss and interact with others. If the laboratory experiment is not a PBL if it is based on a recipe where students have to follow a predetermined path to reach an expected outcome. When students do a scientific experiment by following detailed steps in the textbook, that's hardly any better than passively listening to a lecture. Either way, it's hard for them to see the meaning in what they're doing. But when they create their own investigation design to answer a question that is important to them and their community, they can see how science can be applied to solve important problems.

- Projects are realistic. PBL incorporates real-life challenges where the focus is on authentic problems and solutions have the potential to be implemented in real environments, which is called "situated learning" (Anderson, Reder & Simon, 1996). In the case of science learning, the most effective learning occurs when the learning is situated in an authentic, real-world context. Here it is important to highlight the value of the scientific laboratory as an ideal set-up for "situated learning". There are other ways to experiment with real-life situations, such as observing the natural world and draw conclusions from the observations. Situated learning in science would involve students in experiencing phenomena as they take part in various scientific practices such as designing investigations, making explanations, modeling, and presenting their ideas to others. Furthermore, acquiring information in a meaningful context (Blumenfeld, Soloway, Marx, Krajcik, Guzdial, & Palincsar, 1991) facilitates students make connections between the new information and the prior knowledge to develop better, larger, and more linked conceptual understanding.

- PBL is an instructional method centered on the learner. Instead of using a rigid lesson plan that directs a learner through a specific path of learning outcomes or objectives, project-based learning allows in-depth investigation of a topic worth learning more about (Grant, 2002). In fact, PBL is a student-centered approach, where the learner holds the responsibility of both learning and completing the task and, in most cases of monitoring their own learning. On the other hand, teacher must carefully design the project with well-designed tasks and concrete and feasible final products, thoroughly explain every task to be accomplished, provide detailed directions on the development of the project and encourage student motivation. With regards to project design, teacher must ensure that the project is aligned with curriculum planning and endeavor flexibility to the project so as to attend different learning needs. In addition, assessment might combine different strategies, including formative and summative assessment, and tools for self-evaluation of students learning.

Project-based learning shares most of its characteristics with task-based learning but a project is, by far, more complex than a final task, requires much more planning from the teacher and students are more involved in the learning process, being responsible for their learning and in some extent, for their assessment. In fact, a project is usually comprised of different tasks to be accomplished in a certain period of time. In addition, projects usually involve an ampler spectrum of content, usually involving curriculum integration. The existence of a driving question, the use of projects to deal with core content (not just complementary or reinforcement activities), and the creation of a final artifact are also defining marks of PBL. On the other hand, projects are based on an inquiry process but the teachers role is much more active than in IL, being responsible to carefully plan all the steps in the project and define the outcomes and assessment criteria.

2.2. PBL applied to experimental science learning

Project-based learning perfectly fulfills the requirements for science teaching in a lab setting, as it fits the principles of science learning: learn by doing, collaborative learning, cognitive engagement, and active construction of knowledge. The value of PBL in science teaching, which has been named as “project-based science”, has been acknowledged since the early 1990s, when educators increasingly realized that most students were not motivated to learn science, and students acquired only a superficial understanding of science (Krajcik & Blumenfeld, 2006). This superficial learning was caused by a combination of ineffective textbook design and instructional style. Science textbooks covered many topics at a superficial level, focused on technical vocabulary, failed to consider students’ prior knowledge, lacked coherent explanations of real-world phenomena, and did not give students the opportunity to develop their own explanations to physical phenomena (Reiser, Krajcik, Moje, & Marx, 2003).

In project-based science (PBS), students engage in real, meaningful problems that are important to them, in a similar way to what scientists do. PBS allows students to explore phenomena, investigate questions, draw their own conclusions and discuss their ideas with peers. PBS has also has the potential to help all students – regardless of culture, race, or gender – to engage in and learn science (Krajcik & Blumenfeld, 2006). As mentioned before, PBS is far from following a recipe from a textbook. Even when this is carried out in a lab experiment and let students learn by doing, this is not a PBS approach, because students are not cognitively engaged at their high order thinking skills, as long as they only understand some concepts and apply them in a experiment, In these types of experiments, which are nearer to TBL, students do not require a deeper understanding and they result in only superficial learning.

The value of PBS applied to science teaching has been widely acknowledged. Zumbach, Kumpf and Koch (2004) compared the performance of two fourth-grade science classes taught with the same content a traditional, teacher-centered class and a project-based science class. Students in the PBL class had higher motivation and spent significantly more time out of class working on the project. Veermans and Jarvela (2004) reported similar results, in a study with ten years-old students engaged in a project dealing with mammal's adaptation to the environment. Students participating in the PBL were more focused on learning the topic and collaborated with peers to ask questions and form scientific explanations in answer to the driving questions.

However, PBS can also face some challenging aspects, such as the difficulty in structuring a unit around a driving question that move students toward deeper thinking and understanding (Sage, 1996). PBS might also pose social and emotional challenges for some students (Veermans and Jarvela, 2004), so teachers must s adapt the activity to different educational needs and help students to set goals and monitor their performance so as students do not feel discouraged by the difficulty of the project. The need of more innovative assessment methods going beyond traditional final tests and the need of continuous feedback during the project are perhaps the most challenging aspects of PBS. While final "artifacts" (or the end product of the project) can be used as summative assessment. The challenge of implementing PBS becomes even harder if we need to consider both language and content in a CLIL design.

2.3. Project-based learning in CLIL learning contexts

As aforementioned, using a second language in laboratory sessions can be a challenging task. On the one hand, students need to understand and properly use the language of science to make the utmost of the project. On the other hand, the peculiarities of using a PBL approach should also be considered, as it is intrinsically linked to a collaborative environment, which constantly calls for an effective use of the language.

2.3.1. The language of Science

One of the biggest obstacles that students face in learning science through CLIL is the difficulty in assimilating academic language. If it usually takes several years in acquiring Cognitive Academic Language Proficiency or CALP, as compared to the basic language for communication (basic interpersonal skills or BICS) (Cummins, 1983) it would take even longer in the case of technical scientific vocabulary, which requires advanced levels of literacy, and that the type of instruction is specific to each subject needs (Giouroukakis & Connolly, 2013).

Dominate the language of science pose multiple challenges for English Language Learners (ELLs). On the one hand, scientific vocabulary is plenty of polysemous words used in familiar contexts, such as power, energy, family, compound or element, which usually need a redefinition to give them a more precise meaning in a scientific context. However, teaching science does not only involve applying old words in new contexts but also introducing new words in familiar contexts. A clear example of this is the introduction of abstract concepts occurring beyond our perception, such as relativist theories that make necessary to extrapolate physical events in our macroscopic scale down to a sub-atomic level to interpret atoms and nanostructures, or up to the Universe level to predict the interaction between planets and long-distance forces. There are other added difficulties, such as compound words which are usually challenging to learn (e.g., endocrine system), or science-specific abbreviations, acronyms, and symbols needed to dominate scientific terminology (e.g. H2O) (Giouroukakis & Rauch, 2010).

To the list of challenges ELLs can find in science laboratory sessions we should add the use of particular discourse patterns, such as cause-effect, conditionals and the frequent use of passive voice, which are not familiar to them, or the use of verbs to express skills that rarely appear in other situations such as hypothesize, infer, evaluate or compare. Thus, we can assert that, even though language is important in every subject, it becomes paramount in science teaching.

2.3.2. PBL in CLIL environments

PBL fits perfectly with CLIL environments, where cognition is integrated with content learning and communication. Thus, combination of PBL and second language education is not new. PBL was introduced in second language acquisition as a way to reflect the principles of student centered teaching (Hedge, 1993). In PBL, students receive comprehensible and multimodal input and are challenged to produce comprehensible output (Beckett, 2006) through the creation of a final product or "artifact". As a consequence of the collaborative nature of projects, students have the opportunity to use and recycle language and skills in natural contexts.

When considering language for the project performance, the teacher (adapted from Stoller, 2002):

- Prepares students for the language demands of information gathering. This will depend on the resources and the type of activity that students have to carry out and the final expected outcome. The search of information must be structured and teacher is responsible to provide students with tools for gathering information in a structured manner, for instance, including a grid for organized data collection, providing samples, doing role-play activities if the information includes personal interviews and review of the correct writing format for each task.
- Provides student with the specific language needed to deal with content and the language for the dynamic of classroom (for instance, reading a recipe from an experiment, data collection, data analysis and interpretation of results) and the correct use of basic communication skills (BICS) such as answering/questionings, share ideas or observations, ask for opinions…
- Prepares students for the language demands of compiling and analyzing data. After data collection, students will need to organize and synthesize information that may have been collected from different sources by different individuals. Thus, teacher must introduce students to graphic representations, highlight and establish relationship among ideas, prioritize information, use of supportive resources, check the validity of resources, contrast information…
- Prepares students for the language demands of presentation of the final product. This might entail practicing oral presentation skills and receive feedback about the performance of presentation. If a written report is to be carried out, students might work on the appropriate scientific register, work on

the content-related language (CALP) and on the grammar requirements (such as passive voice, past tenses, cause-effect relationships of events...).
- Provides and use appropriate assessment tools adapted to each product, taking into account the different dimensions of language in CLIL (language of, for and through) and the different formats used (reading, writing, speaking and listening).

3. Analysis

In this Research Proposal the main points to consider to successfully implementing CLIL methodology in laboratory practice are discussed, and the potential benefits and challenges of this integration are analysed. The methodology used will be based on the qualitative analysis of documents reported in bibliography. The research will be based on the hypothesis that CLIL methodology and laboratory practice share many common aspects, therefore, developing lab experiments may offer valuable opportunities for learning the language through authentic and meaningful activities.

3.1. Setting up a CLIL-based PBL laboratory activity

Project design is flexible and can be adapted to different learning experiences. However, there are some common features that well-designed projects must include (Grant, 2002):

- an introduction to "set the stage" or anchor the activity; this must include a pre-task (such as self-reflection or brain-storming) to activate prior knowledge and to make a clear connection of the activity and the underlying concepts that students must attain,
- a guiding or driving question that triggers students' curiosity, so that they get cognitively engaged,
- a process or investigation that results in the creation of one or more sharable end-product; through the creative construction of a meaningful artifact, which may be a play, a presentation or a poster, which is created by students to represent what they've learned,
- resources, such as subject-matter experts, textbooks and hypertext links,
- scaffolding, such as visual organizers, videos or realia, to help learners to progress through the project,
- collaboration, including team work, peer assessment and external content specialists, and

- opportunities for reflection and transfer, such as classroom debriefing sessions and extension activities.

There are different possibilities to design a project, but it is usual to start by defining the intended result or final product and then design backwards in terms of task, language necessary and curriculum planning. Ravitz et al. (2004) propose the following template to design a PBL activity (p.2):

a) Begin with the end in mind and explain the expected result.
b) Craft the driving question; select and refine a central question.
c) Plan the assessment and define outcomes and assessment criteria
d) Map the project. Structure the activities, cross-curricular links…
e) Manage the process: find scaffolding strategies and tools for successful projects.

The success of the lab experiment depend on the establishment of an appropriate plan, thus, we propose different aspects to consider when planning the activity:

- Consider the CLIL dimension. The 4Cs framework can be a good starting point, as it provides a holistic view of the dimensions to be included in CLIL planning, namely content, cognition, communication and culture. Project-based lab experiments offer multiple opportunities to include the CLIL dimension by any of these aspects, so they have to be clearly stated and reflected in project planning.

- Setting the aims of the activity: together with the general aim, which can be stated through the driving question, the objectives with respect to the content, language and cognitive skills should be clearly specified and planned before starting the activity. This plan is, however, flexible enough to foster students' creativity, letting room for their ideas and any related topic or activity that may arise during the activity.

- Planning the activity, which implies the search and adaptation of materials to be used in the lab and resources from texts and web, the design of the lab experiment, the formulation the tasks that will be included to progress in the project, the identification of one or more questions representing the aim of the experimental activity; prediction of the results.

- Connecting with prior knowledge: content should not be completely new for students, so that they can construct using their prior knowledge. It is interesting to include an initial phase were students go through content before the before the experimental activity. With regard to the language, it can be interesting to provide students with a glossary of terms to facilitate communication using the correct terminology.

- Developing the experiment, which refers to the design and performance of the experimental activity, data collection, analysis and evaluation; formative assessment during the activity;

- Creation of an artifact: filing a lab report, share results with the rest of the class, plenary discussion on results and conclusions; comparison between predictions and results; evaluation of experimental procedures; individual assessment on the laboratory report; summative assessment.

3.1.1. Begin with the end in mind

When designing a project, it is important to start by defining what we expect to achieve by means of the project and work backwards, taking into account what students already know, what they need to be taught and what they would discover by themselves. Starting by the end implies that we are emphasizing this end as the main objective of the project, and that it is worthy or has any important application. When first defining the project it is important to bear in mind which scientific concepts we want them to learn and work with and if the expected result would fit with the purpose. As previously defined, projects deal with concepts that are core to the curriculum, so it is important to define which concepts are dealt in the project and foresee which learning criteria and standards are involved in the project.

If the project involves different subjects, it should include an effective coordination between the different teachers to split the project into the different concepts and skills students will need to move forward in the project. From a CLIL prospective, coordination between content and language teachers is always mandatory, thus, they have to discuss in advance the language needs of the project and what are the language goals of the project. So in this first step of planning, teachers have to work in coordination and set up the basis of the project from each perspective.

In summary, this first step in project planning is devoted to outline the project, considering what the general aim is, what we expect to achieve and its suitability. Thus, it is important to consider, in broad terms, the following aspects:

a. Summarize the theme for this project. Why do this project?
b. What do we plan to achieve? What is the general goal?
c. Outline the main content parts that students will learn in this project.
d. Identify key skills students will learn in this project.
e. How will we promote language learning and use?
f. Does the project fit with the students′ background?
g. Is the project feasible in terms of resources, time, health and safety considerations, students′ age and maturity? If it is not the case, is it adaptable to our needs?
h. What possible pitfalls could arise?
i. Does the project fit to purpose?

This initial exploration would help us to decide if the project is feasible and worthy.

3.1.2. Contextualize the project

In this part of project planning basic information about the work group, subject, areas involved, main topic or unit, language level, difficulty, safety considerations, timing, etc.

3.1.3. Craft the driving question

The driving question is an open-ended question that sets the stage for the project by creating interest and curiosity. Writing an effective driving question can be surprisingly challenging (Vincent, 2014). On the one hand, the question has to be intriguing and irresistible to students so that they feel motivated towards the investigation. Thus it should not resemble at all to the typical questions they encounter on tests. It must also be complex, good questions can't be answered with a simple "yes" or "no," and a search on the Internet would not turn up the solution. A complex driving question sets the stage for action and makes students ask, "What can we do about this issue?". In addition, it is substantial and must capture the heart of the project by providing purpose using clear and compelling language. In fact, the driving question is used to introduce the topic while suggesting why the project can be relevant to them. Driving questions also pose simply stated real world dilemmas, predicaments that students find interesting and actually want to answer. Good questions must be challenging, and encourage higher-order thinking skills such as making connections and inferences, evaluating, applying existing information to solve new problems, or create. Thus, the question drives students to discuss, inquire, and investigate the topic.

It should push them toward a production or solution. In the process of investigating the question and sharing their answers, students learn important content and skills. Thus, we can assert that the driving question is the *driving force* of the project.

From a first sight, the students can feel discouraged if they find the driving question too challenging to solve for them. Therefore, a good driving question will lead to more sub-questions by splitting the whole problem into more approachable intermediate states. These sub-questions, which derive from the main question and from other intermediates, are specific and can guide student research. Branching questions get students thinking about what they need to know to answer the driving question.

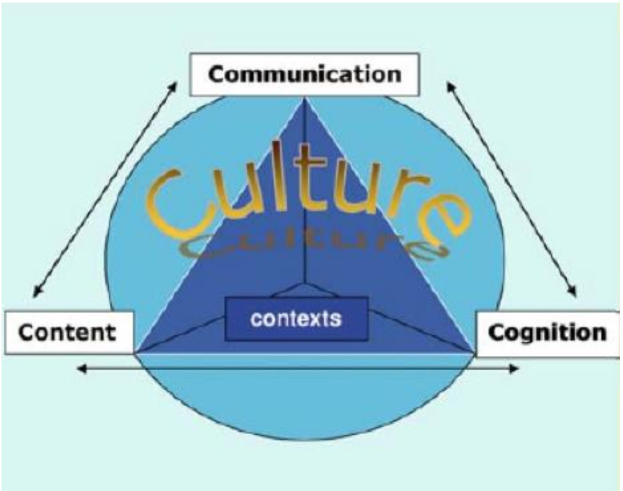
To formulate and prove the effectiveness of the driving question, we should consider the following aspects (Vincent, 2014):

- the question is appealing to students,
- the question connects students' interests and passions,
- the question does not sound like a test question,
- the question leads to more questions,
- there is more than one answer to the question,
- the topic is personal or connect with local issues,
- students can relate to the question in their daily lives,
- the question is clear and concise,
- the question requires serious investigation,
- the question introduces what important skills and content students will learn,
- the question has no easy answer,
- the project will somehow make a difference in the world.

3.1.4. Outline the CLIL dimension

Although the integration of language and content should be present at every point of the planning of the project, it is worthy to include this point at the beginning and take time to reflect on how CLIL would impact the project. Coyle, Hood and Marsh (2010) suggest using the 4Cs Framework to plan a CLIL unit, as summarized in Figure 1. As can be seen, the figure highlights the role of culture in the center of the tetrahedron, as a way to remark that although it is usually forgotten, it plays a central role and must be emphasized. Together with the 4Cs, contexts are included as the scenario for meaningful and lifelong learning.

Figure 1. The 4Cs Framework



Adapted from Coyle (2005, p.8)

On the same basis, the 4C´s can also be considered to implement the CLIL dimensions in the project. The 4Cs are referred to:

Content, which refers to the knowledge, skills and understanding learners might be able to access, rather than simply knowledge acquisition.

Communication, implies considering language as a conduit for communication and for learning. The language dimension can be described as "*learning to use language and using language to learn"*.

Cognition, as learners must be challenged to create new knowledge and develop new skills through reflection and engagement in higher-order and lower-order thinking.

*Culture, usually considered as the "forgotten C", it refers to "*self" and "other" awareness, identity, citizenship, and progression towards multicultural understanding.

Integrating the 4Cs in the project can be helpful to design the type of tasks that should be carried out to have a holistic view of the topic. In fact, although these parts should be implicitly included in the project, they might not be properly weighted or interconnected so it is important to make a reflection on each of them. Content is always the common thread of the project and it is explicitly or implicitly included throughout the project. With respect to communication, it can be easily considered by working in groups or by including a final product that has to be presented. However, it is not so straightforward to include cognition in our planning. It can be useful to include it interweaved with any of the other dimensions. For instance, we can foster communication beyond just preparing a text to be presented in class, but use cognitively demanding tasks to promote students' thinking skills, where they have to describe a process, analyse results, take conclusions, extrapolate to other physical phenomena, infer ideas, discuss, imagine consequences… Although culture might seem difficult to integrate at first sight, scientific projects have a real world projection that can be exploited to connect with the cultural dimension, usually by environmentally friendly attitudes around the topic. Here there are some aspects to consider in project planning:

(i) "C" for content

The Spanish curriculum organises content in subjects, in concepts, procedures and attitudes that students will gain during the learning. Thus, it can be worthy to organise content in the project in a similar manner. Needless to say that "content" is more than merely covering concepts in a unit or part of a unit. Students will have the opportunity to learn scientific habits to put in practice in a lab through experimentation, which entails considering safety and responsibility aspects, manipulative skills and organization habits, among others. In general terms, in the area of Science (Real Decreto 126/2014), contents are organized around fundamental concepts related with the initiation of the scientific activity, living things, human beings, technology (…), thus allowing students in advancing to acquire the scientific knowledge. With respect to procedural content, they are related to "to know-how", so students are due to be initiated in common strategies and techniques in science, such as observation, identification and analysis of scientific questions, collection, organization and treatment of data, hypothesizing, design and development of investigation (…), and communication of results. With regards to attitudes, content should promote curiosity, interest and "self" and "other" respect, respect for the environment and science, group working and collaboration.

Therefore, lab experiments are reflected in most of the aspects defined for content in scientific subjects. All in all, content in projects must include:

Concepts: When defining the concepts to be included in the project there should be born in mind that:

- Content must be central to the curriculum, so that projects are not complementary tasks to reinforce previously acquired knowledge. Thus, content must be new and must be reflected in the curriculum.
- When possible, there should appear cross-curricular connections. Projects are more fruitful if there are more than one subject or transversal knowledge involved. Due to the CLIL dimension, the language dimension is necessarily considered. Nevertheless, as many connections among subjects as possible should be done to impact on the holistic vision of the curriculum.
- New content must be anchored to prior knowledge so that students can construct on their own learning. Making connections with experience and prior knowledge would help students to work with autonomously and not being overwhelmed with content that is too abstract or too strange to them.
- Although scientific concepts do not appear always explicitly (for instance, it might not be stated in the driving question), they are always the common thread during the project. Thus, they should be structured in a logical progression and culminate in a creative task where students put in practice their acquired knowledge.
- Concepts are linked to language. Students must be provided with a word bank that appropriately caters them to progress during the project. Language cannot be the limiting factor in acquiring content.

Attitudes: mainly referred to attitudes and mind habits to put in practice in an experimental task (particularly in lab) in science:

- Be preventive and cautious and consider safety risks and appropriate behaviour in a scientific laboratory. The scientific laboratory is plenty of risks and potential dangers that students should know in advance. This should not prevent teachers to use the lab as it is a valuable set up for learning and it is present in most of high schools. Quite the contrary, students might learn all the implications of working in a scientific lab, and health and safety considerations are usually the starting point. Burns, cuts, contact with hazardous chemicals, inhalation, biological hazards, electrical safety, flammable liquids, potential explosions, heating, glassware handling, noise, are just some of the potential risk that can occur in the lab and that students must be aware of aware of.
- Be critical and rigorous in observing experimental phenomena. It involves considering all the variables, being objective and avoiding biased results by our

observation, practice patience and attention, be ready for unpredictable facts and results, etc.

- Be open to reinterpret previous experience to accommodate new learning. A good project usually involves a change of mind for many well-settle facts that might find a scientific explanation far from the expectation. For instance, using the microscopic theories to explain a macroscopic observation (*i.e.* a change of colour in a chemical reaction, changes in the state of the matter, the effect of temperature on physical and chemical processes).
- Value the importance of scientific facts and explanations applied to quotidian facts. As aforementioned, projects are necessarily connected to real life. The application of new learning to real life should be explicitly stated and students might reflect on the consequences and alternatives. This can be used as a way to connect with culture, as the students mind gain environmentally friendly habits at any available opportunity.
- Work as a part of a team in carrying out experiments, respecting other working abilities and ideas, collaborate to solve a problem and as part of a scientific community.

Procedures and skills. Lab experiments are based in experiential learning so they are in essence manipulative. In addition, projects are based on learning by doing. Thus, there are plenty of examples of procedures and skills that can be acquired throughout scientific projects, just to mention some of them:

- Carrying out a lab experiment
- Representing data (tables, figures, schemes…)
- Comprehensive reading of a text with scientific terminology
- Analysing results and extract conclusions
- Writing scientific reports and laboratory notebooks
- Presenting results
- Interpreting physical phenomena

(ii) “C” for communication

There are two dimensions that should be covered in the project with regard to communication. On the one hand, the basic linguistic forms that learners will need to express themselves properly in a scientific context should be explicitly included. For instance, in a chemistry experiment, students will need to use the past tense to give an explanation of a chemical reaction or to report the process, and the present tense to write or read a lab recipe or express a general fact. These are part of the 'norms' of reporting a science experiment. Knowing and dominating the scientific language in the appropriate context is basic for their future development, although this might not satisfy the cognitive demands, as it just consists in applying some given rules to a particular context. As part of these basic linguistic forms, there can be distinguished, those that are used for (Cambridge, 2011, p.3):

- Describing characteristics. Example: elements are composed by subatomic particles, such as electrons, neutrons and protons.
- Explaining a process. Example: separation of solutions into its parts is carried out by fractional distillation, which consists in heating up the mixture until each of the components boils, then the pure components in fractions condensate in separate compartments.
- Describing functions. Example: proteins can have different functions, such as cell signalling, ligand binding, catalysing processes as enzymes, or forming structures
- Expressing purpose. Example: haemoglobin contains iron in its structures that serves to bind oxygen.

On the other hand, students should have the opportunity to communicate and express themselves. Thus, students need a variety of opportunities to work on communicative tasks, which can include brainstorming, work in groups, debates, presentation and feedback or questions/answers individually or in groups, among others. As projects are open-ended, they are usually open to debate, new ideas or additional data to support their arguments, thus students might have (or learn) the tools to express themselves in an unforeseeable discussions that goes beyond using inappropriate tenses or to using language phrases which are cognitively undemanding. Thus, the communication skills might be leveled as much as possible to the cognitive demands of the project, so as to cater their needs to move on the project while progressing in language acquisition, use and confidence, without being demotivated or confused by too-demanding language needs; this might require adaptation of materials or tasks but this not necessarily means sacrificing content or cognitive demands of the project. As in projects students construct their own knowledge, they are not expected to work on their own but in collaboration with peers and guided by the teacher. Thus, the communicative dimension is core to projects.

Coyle et al. (2010) propose consider the “language triptych” –*language of learning, language for learning and language through learning*– in communication to detect and foresee the language demands, as it is summarized in figure 2.

With regards to the language *of* learning, it is referred to language that learners will need to access and understand new knowledge when dealing with the content. In the case of science projects, it can include:

- Developing and use a proper scientific genre: encourage a tone of objectivity, personal pronouns should not dominate the writing.
- Gaining knowledge of scientific vocabulary, terminology, and general scientific language (i.e. symbols, magnitudes, units…).
- Using appropriate verb tenses to write a report, express general assertions.
- Working on grammar constructions to express cause-effect relationships, use of passive voice and impersonal structures.
- Using present tense for established facts (e.g. previously published in a peer reviewed journal) and past tense for the work and findings you are presenting.

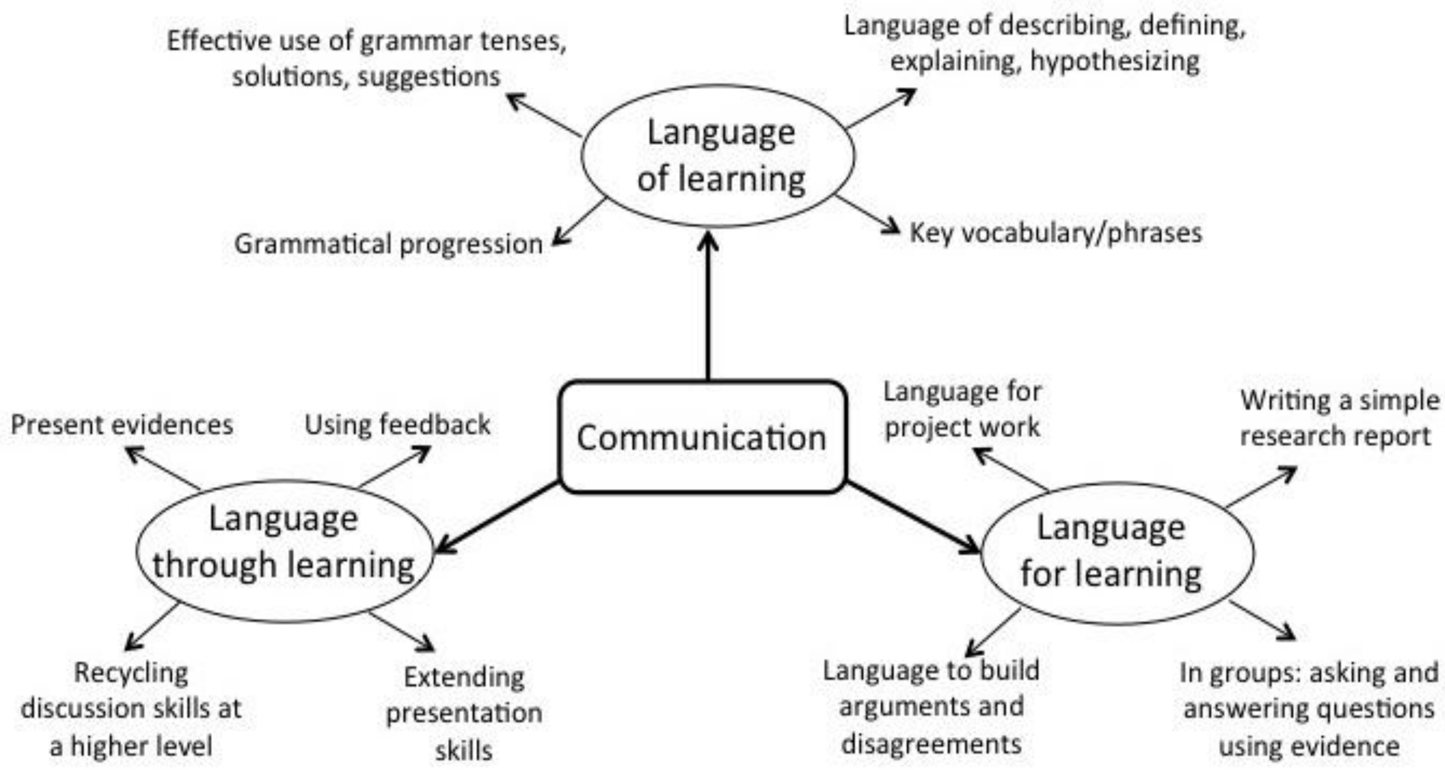
In the case of language *for* learning, which refers to language that learners need to operate effectively in a CLIL context, science projects includes opportunities to use language for:

- Inferring ideas
- Making predictions
- Building arguments and disagreements
- Writing a lab report
- Working effectively in groups

Language *through* learning is referred to the language that emerges from specific learning contexts, which is needed to support and advance the students thinking processes whilst acquiring new knowledge. Language through learning means to capture language as it is needed during the learning process, which can be spontaneous or planned. This can be associated to the language used to different situations that might require new language skills, such as:

- Recycling discussion skills, which means their previous skills adapted to new situations that might emerge during project development.
- Using feedback to extend their language and notions in new ways, access to new language and, making feedback effective after internalization.
- Widening language for effective communication in a range of situations such as expressing opinions, explaining processes, present evidences

Figure 2. The language triptych in CLIL



Adapted from Coyle et al. 2010 (pp. 61-63) *(iii) <u>"C" for cognition</u>*

According to Bloom's revised Taxonomy (Krathwohl, 2002), in any learning process, students need first to remember and understand content to later apply their knowledge. Only then they will be able to analyse and evaluate it so as to finally be able to create. Thus, there must be a cognitive progression from the lower order thinking skills (L.O.T.S.) to the higher order thinking skills (H.O.T.S.).

Bloom's revised taxonomy is an approach for promoting critical thinking by six distinctive categories of cognitive objectives (Krathwohl, 2002):

- *Remember:* Remembering involves recall knowledge from long-term memory. For instance, remember content to be put in practice in the activity.
- *Understand:* the students should be able to explain the acquired content
- *Apply:* This thinking dimension involves put in practice concepts in the experimental activity carried out in the lab.
- *Analyze:* breaking down the acquired information into parts and see what are the connections among them Analyze involve get information from the experiment. Analyze involves extract data from the experiment, which is related to the content. The rawdata obtained in the experiment can be quantitative (i.e. a concentration of a given substance) or qualitative (observation of a physical phenomenon, such as a colorimetric change as a consequence of a chemical reaction)
- *Evaluate:* involves synthesizing the acquired information, creating an opinion and arguing. Evaluation can imply correlate the extracted information from the rawdata with the concepts behind the phenomena, find an explanation to the results obtained
- *Create:* is related to the ability of getting anything new out of the input given. Create means being creative and innovate to apply the learning in a different situation. For instance, students can extrapolate the experiment to similar situations in the Nature, such as physical phenomena in the environment that may impact their lives to some extent.

Scientific experiments can be very intuitive when considering this progression from LOTS to HOTS in a natural way. Thus, in a science experiment, students have to:

- Recognise the reagents and lab material necessary for an experiment (cognitive category: remember).
- Explain how to carry out the experiment (Cognitive category: understand).
- Do the experiment and obtain results (cognitive category: apply).

- Analyse results (cognitive category: analyse)
- Extract conclusions (cognitive category: evaluate)
- Make a poster to present the process and results of the experiment (cognitive category: create).

A project-based work is always oriented to creativity as the last stage of the process, where they have to create a product or artefact to culminate the project. However, there are plenty of opportunities to exercise cognition throughout the project by means of task of different complexity that helps to develop the project. These tasks can be carried out at the beginning to anchor with prior knowledge and to introduce new content, look for information and extract compare and contrast the main ideas to complement the experimental work (for instance, to contextualize the topic and see the impact it may have to life) or during the experiment, where the students have to manipulate and interact with the physical media to obtain some results and solve a problem through experimentation. Thus, cognition must be present when planning activities or tasks to be carried out during the project.

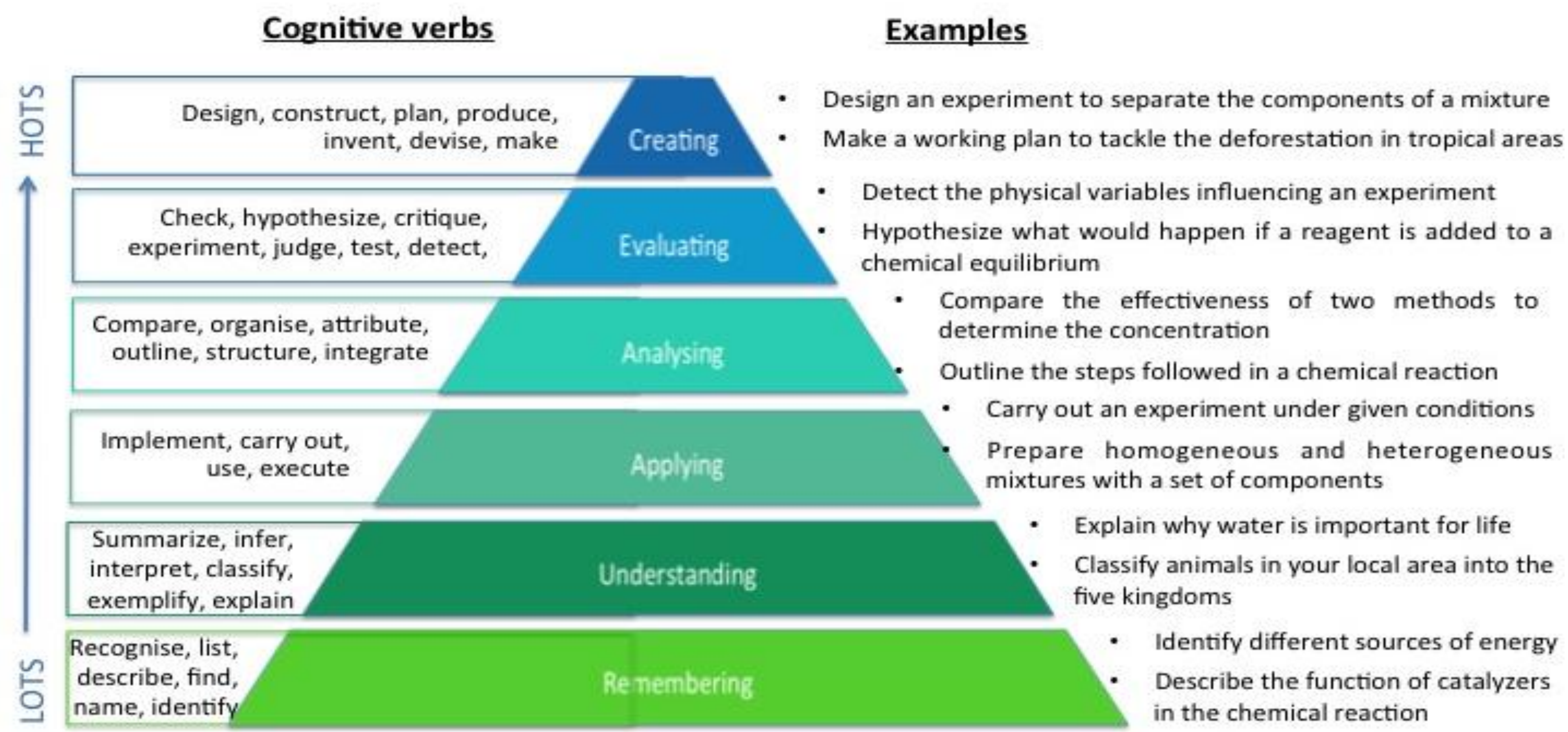
Figure 3 shows some examples of how the different cognitive categories can be applied to science experiments. Some examples of cognitive verbs that can be useful to define objectives based in Bloom's revised taxonomy at the different categories are also listed in the figure.

It is worth noting that cognition and content are usually tied and they are stated together in objectives and assessment criteria. Thus, when planning objective: "Propose a set of alternatives for reducing dependence on fossil fuels" the verb "propose", is related to the taxonomic category "create", and has no meaning by itself if it is not linked to the content part "fossil fuels and alternative combustibles". Thus, it can be logical to structure content from simple to complex and, accordingly, to structure objectives (thus tasks and assessment), following a cognitive progression from LOTS to HOTS to fulfil the requirements for content and cognition at the end of the unit.

(iv) "C" for culture

It is important for science teachers to understand the cultural reality of students and the cultural diversity, so that these cultural aspects are brought to class, because, "science education is successful only to the extent that science can find a niche in the cognitive and socio-cultural context of students" (Cobern, 1991). Medina-Jerez's (2008, p. 209) showed that "the acknowledgement of cultural differences in the classroom provides the needed attention to each student in coping with his/her strengths and

Figure 3. Bloom's revised taxonomy and some examples of its application to science experiments.



Adapted from Krathwohl, 2002

weaknesses as they feel integrated into the cross-cultural scenario of the classroom”. Thus, including the cultural dimension in CLIL is a way to cope with self and others identities and cope with cultural differences present in the learning environment.

When planning a CLIL-based science project, reflecting in some of these questions can enrich the learning opportunities:

- What do students believe about the world around them, especially the physical world?
- How do students understand their own place in the world, especially their relationship to the physical world?
- What is the cultural context in which students beliefs, values, and relationships are grounded and supported?
- How science impacts on cultural, economical and political aspects and how can it be used to improve the quality of life?
- What is the culture of science and how is that culture interpreted in the science subject?
- How students can change their habits to have an environmentally friendly behavior?
- How can we take advantage of the use of a foreign language in the project development?

A common way to promote culture in science projects is by including the civic learning dimension (21st CCLC, 2014). In civic learning, students are connected to meaningful opportunities for collaborating and engaging with others, typically government and community groups. Civic learning is a powerful tool for helping students understand that they can make a difference in the world around them while gaining important academic and 21st century skills. It starts with students identifying a public issue of personal concern (*i.e.* climatic change, pollution, or recycling), which leads to seeing themselves in a more meaningful role in their community, their nation, and the world. The process involves collaborative brainstorming, problem solving, and action and encourages students to explore in-depth an issue they have chosen. Civic learning can strengthen their civic consciousness and help them develop an appreciation of their potential impact on society and environment. Projects can be used to awaken students’ awareness towards topical issues that might be relevant to their lives and make them get involved as active citizens. Therefore, the cultural dimension might be taken into account when selecting the central topic of the project to connect with their interests.

However, there are usually multiple opportunities to promote culture directly or indirectly, other than (or together with) by civic learning. Thus, using a CLIL environment provides another dimension to multiculturalism so teacher should take advantage of the role of language and consider the added value of carrying out the project through another language. For instance, language can be the means to first-hand read or listen to real news on the topic or investigate on different perspectives and implications throughout the world. As English is the most widespread language in the scientific community, students can also read scientific articles to familiarize with the state-of-the-art in a particular topic that might be interesting for them and arouse their curiosity, for instance, how cars will be in the future, the use of renewable combustibles and alternatives to petroleum, the use of "intelligent windows", new materials that will revolutionize technology, such as graphene or nanocarbon tubes, the recent discovery of new elements in the periodic table, or revolutionary theories about the universe such as " The Theory of Everything", or the "String Theory".

As scientific experiments and projects are based in the "learning-by-doing" principle, they must be somehow connected with real world. Students will need to extrapolate the experiment to the "outer world", in other words, introducing culture in science experiments means to bring a context to the scientific topic or to contextualize science. Contextualize science can include: (a) reflect on social movements around diseases or environmental issues, (b) bring about economical implications, (c) science-related moral/ethical issues, or (d) the political world of regulations and policymaking. Thus, introducing the cultural dimension in science-based projects might involve, for instance, how their country contributes to the development of pharmaceuticals against cancer, for instance. It can also include, investigating patterns in different cultures (i.e. pollution levels in different countries, use of different types of combustibles and their impact on the environment, recycling patterns...), or even get involved in join projects with schools form different countries to compare results and exchange ideas.

3.1.5. Define the outcomes

In CLIL projects, learning outcomes can be divided into those which focus on science content and those which focus on content and language, in the latter, teachers should notice which of them need language support. However, a CLIL-based science project is more than learning content and language, but there are

It is important that students know in advance about learning outcomes, so that they are clear about what they should understand and achieve by the end of the project. Learning outcomes should be based on the 4Cs framework, taking into account that content and cognition are usually linked when defining the learning objectives.

3.1.6. Align Products with Outcomes

Once the outcomes for the project have been defined, planning effective assessment requires working backwards to align the products or performances for the project with the outcomes. In projects, the final product is usually referred to as "artifact". Artifacts are representations of learning, public presentations of the learner's solution to the guiding question. The production of the learning artifact is what essentially distinguishes project-based learning from other approaches such as task-based learning. In fact, the emphasis in project-based learning may center on the production of a learning artifact, while in task-based learning the final product seems to be less cognitively demanding (Grant, 2009).

Artifacts are representations, reports, or models that are completed as a result at the end of the project, once the problem posed by the driving question is solved. Thus, the artifact is not just part of the learning process, but the culmination of it in a creative production, as it usually requires that students demonstrate their knowledge and cognitive skills to produce the artifact. In fact, to complete the artifacts in the final creative stage, students need to investigate, think, reflect, draft, and test hypotheses. Much of this work takes place in a collaborative mode. The value of artifacts is that they are engaged in active learning, which is one of the goals of PBL. These products should provide adequate evidence of student learning and achievement, giving students the opportunity through the products to demonstrate what they have learnt.

As an added value of artifacts, they must be varied and rich with regards to language demands; thus, language production should be present in a variety of modes (including oral and written production). For instance, final reports can be complemented with oral presentations and a global discussion with feedback from the rest of the class, so that students practice writing and speaking, and work in a communicative task.

Examples of artifacts are:

a. *Laboratory notebooks*. Laboratory notebooks are a form of authentic materials, as they replicate what scientists actually do (Quinnell, Hibbert & Milsted, 2009). Students use the notebook to record details of the experiments, such as methods, tools and results. Using lab notebooks as part of the assessment reinforces the value of documenting laboratory work. However, as laboratory notebooks are not usually presented to the rest of the class, this type of artifacts are lacking the communicative dimension, so the oral presentation and peer discussion is missed.

b. *Final reports*. This is another example of authentic materials but, unlike lab notebooks, they are prepared at the end of the experiment. Reports are valuable samples of the writing skills of students and they have to be explicitly taught, as students are not used to the scientific register and genre of scientific text. This might involve using report templates based on the scientific method, so that students gain first-hand knowledge on how scientific investigation takes place. In addition, they can be used to monitor students' observation, interpretation and reflection abilities, and to infer the knowledge and skills developed through lab-based learning.

c. *Posters*. In addition to being a unique sample of authentic materials and presentation, posters engage students cognitively to develop their observational, analytical and communication skills, and encourage them to be creative and reflective. Posters are usually carried out in groups and usually involve a presentation session, where teachers and peers can assess the posters, giving the students fast and formative feedback. With regard to language assessment, communicative oral and writing skills can be developed at once. If posters are to be used as artifacts, it is important that students receive clear instructions on what to include (objectives, results, interpretation and analysis), making it clear that this is a type of scientific final product. Using samples of posters used in real conferences can give an idea of what students are expected to do.

d. *Oral presentations*. Students (in groups) can present an experiment or set of experiments to their peers and report findings, challenges and implications. As in posters, either peer or tutor assessment can be used.

3.1.7. Plan the assessment

Planning the assessment in projects is a step that comes before the project begins in the classroom. Good assessment practices mean that students should know exactly what will be required of them, and what criteria will be used to evaluate their performance. Assessment in projects should be balanced, which implies including a variety of assessments closely tied to the outcomes, the content standards, skills, and habits of mind-of the project. Most important, multiple indicators for performance give different kinds of students, each with different strengths, the opportunity to succeed.

The assessment plan should include both formative assessment –assessment that allows giving feedback as the project progresses– and summative assessment –assessment that provides students with a culminating appraisal of their performance.

Assessment should aim at monitoring the students' progression considering the following aspects (UNSW, 2015):

- technical and manipulative skills in using laboratory equipment, tools, materials, computer software
- understanding of laboratory procedures, including health and safety, and scientific methods
- a deeper understanding of abstract concepts and theories gained by experiencing and visualizing them as authentic phenomena
- the skills of scientific enquiry and problem-solving, which might include:
  - recognising and defining a problem
  - formulating hypotheses
  - designing experiments
  - collecting data through observation and/or experimentation
  - interpreting data
  - testing hypotheses
  - drawing conclusions
  - communicating processes, outcomes and their implications.
- the complementary skills of collaborative learning and teamwork in laboratory settings

When planning assessment we must ensure that the four dimensions of language –reading, listening, writing and speaking–, are included in activities. Reading can be assessed, for instance, including a scientific text with final questions, to prove their understanding on the test. This can be included during an initial exploration of the topic (*i.e.* read a new on the environmental impact of the topic). There are multiple ways to include speaking activities that can be used for assessment, such as brainstorming, group discussions or presentations. Reports, posters or lab notebooks can be used to assess the writing. Having an expert in the class or including videos can be used as listening activities that can be used for assessment too.

Assessment in lab experiments can be approached from different perspectives, depending on the type of experiment:

- An experiment can serve to *engage prior knowledge, thus,* it can be used to assess the skills and knowledge that students have acquired in previous class lessons in order to complete the experiment. In this way, the experiment could be seen as an assessment *of* learning, where students will be required to predict, use their knowledge, *and* expand from the knowledge given to them, using their own creativity, ideas, and inquisitiveness in order to complete the experiment. In this way, the experiment may be seen as an assessment *as* learning. However, this does not entirely fits with the principles of PBL, as knowledge involved in the experiment cannot be a complement of theory but a central activity to acquire new content. Thus, the lab experiment in projects cannot be seen as a mere instrument for assessing what students have learnt.

- An experiment may also be used as a *summative* assessment at the end of a unit or lesson. Instead of a formal test of terms and definitions, students may perform an experiment in order to demonstrate their knowledge. The final result of the experiment can be used for the assessment. This can be the case of calculate the concentration of a component in a mixture. The final concentration calculated by the students after the experiment can be used as a product that can be assessed by the teacher. This type of assessment simulates the final product of a real lab experiment (as it happen in real lab of analysis). However, this evaluation is rather limited and should be complemented with formative assessment, as not reaching the final result does not necessary means that the whole experiment has failed and the learning process has to be null; moreover, students should not fail from the pressure of getting the right result, and they might also value that it is difficult to control all the variables in the experimental process.

Projects offer multiple opportunities to monitor students' progress in a context where students are working with autonomy, thus it can be more effective than relying only in the final product. Multimodal assessment aims at providing multiple opportunities for the students to demonstrate their achievements. In projects, it usually consists in collecting samples of work progress during the early, middle, or late stages of the project, each of them should yield information on students' progression and build the skills and knowledge to advance in the project. These activities can include preliminary and culminating products and can be produced by individuals and/or groups.

Using multimodal assessment in projects provides teacher with more control over the process, and allows an early look at whether students are meeting the goals of the project or encountering unforeseen problems, allowing, for instance, to decide alternative directions, make realistic estimates of the amount of time necessary for project completion. On the other hand, it offers students multiple opportunities to demonstrate their learning and proficiencies, and helps them to organize their work and refine and improve their work.

In projects, multimodal assessment can include several of these tools:

e. *Observation*. Observation is part of the formative assessment and it should include feedback, as a part of teachers' guidance, so that students will be directed through the project. Observation is not an random process, but it has to be systematically planned and recorded, and both student and teacher must have clear what is being assessed by means of rubrics. Observation should include taking notes or making records including samples of students' work to be used in a final evaluation.

f. *Self and peer assessment*. Students might be involved in their own assessment and reflect on their own progression and achievements as part of the autonomous learning and their cognitive development through the analysis of results. This is a way of *assessment as learning*, as it is part of the project and aims at improving the students' learning process. The project might also offer the opportunity to involve others in assessing by observation and recording, for instance, by encouraging students to note their observations on critical events at the time of their experiments, so that they can discuss them, thus developing their communication and thinking skills.

g. *Pre-tasks and intermediate activities*. Use tasks or activities during the project can help to move on the learning, reinforcing concepts and key ideas, developing vocabulary, while including assessment practices, such as tests.

h. *Exams*. Lab sessions are usually accompanied by final exams, which can be valuable but may not be complete enough to assess skills or communication and to cater the different students' needs. Thus, they should be complemented by any or several of the aforementioned assessment methods.

i. *Artifacts*. Artifacts are, undoubtedly, valuable tools for assessment, as they can be the evidence that the process of planning, questioning, and problem solving has occurred. Artifacts can be used to evaluate concepts, skills and habits of mind (the main components of content). For artifacts to be effective, standards and expectations for them must be established and shared with students in advance, what is to say, students need a clear idea of what it is expected from them. Samples of real work (such as scientific papers or posters) might be very useful. As the scientific work is probably new for them, it is convenient to provide with schemas of the scientific methodology at the beginning of the project, so that students know in advance what they have to accomplish, and to encourage them for record keeping and note taking during the project. After evidences are collected, they can be used as constructive feedback to students, for instance in a final session (which can be presented as a formal scientific meeting) to present their work in groups and with the collaboration of the rest of the class, where they have to ask pertinent questions and argue about conclusions.

Assessment in lab-based projects can be challenging, especially when the CLIL dimension has to be included. This is partly due to the fact that laboratory experiments usually have wide-ranging objectives, spanning practical and motor skills, broader understanding of concepts and theories, and higher-level thinking and reasoning skills of scientific enquiry. Thus, it can be a challenge to design assessment methods that capture student learning that is based on active learning (hands-on, motor skills) through a scientific enquiry. Assessing the performance of scientific enquiry would be based in establishing the level of independence and autonomy for which a rubric might be used (Fay, Grove, Towns & Bretz, 2007), so that requirements for task completion are clearly stated and understood by students, and in order to develop the criteria for assessing task performance. In the model shown in Table 1, higher levels of scientific enquiry are graded progressively.

Table 1. Scientific enquiry rubric

Level of enquiry	Description
0	The problem, procedure and methods for achieving solutions are provided to the student. The student performs the experiment and verifies the results with the manual.
1	The problem and procedure are provided to the student. The student interprets the data in order to propose viable solutions.
2	The problem is provided to the student. The student develops a procedure for investigating the problem, decides what data to gather, and interprets the data in order to propose viable solutions.
3	A "raw" phenomenon is provided to the student. The student chooses the problems to explore, develops a procedure for investigating the problem, decides what data to gather, and interprets the data in order to propose viable solutions.

Adapted from Fay et al. 2007

As it is difficult to design a lab experiment that fits to all the enquiry levels stated in the model rubric, it can be easier to associate laboratory-based learning with a wide range of possible learning outcomes through the aforementioned multimodal assessment tools, with increased emphasis on artifacts as a creative culmination of their work. This can be more approachable than trying to assess, for instance, increased interest and enjoyment in the subject, hands-on engagement, even though these outcomes might be highly desirable.

3.1.8. Map the project

Once the end has been outlined, the Project has to be structured so that students learn and practice the skills, content and language that have been planned. This includes to plan what students need to know before they undertake the Project, what they will need to succeed and solve the posed problem, or what they will learn on their own as part of the autonomous learning.

In order to make projects more manageable, it can be worth breaking it down into tasks, structured by the content, communicative dimension, language practice or cognitive skills that are going to be promoted on each. Table 2 shows some possible tasks that can be used at different steps of the project, classified according to the skills promoted. Experimental work is implicitly included in all of them, but is directly related to hypothesis testing, problem solving, decision-making and analysis.

When mapping the project, it has to be born in mind practical questions such as:

- Time. Projects are usually time-consuming and experimental work is sometimes unpredictable (experiment might fail, students are not familiar with experimental work or do not understand protocols…), so time planning has to be realistic. Otherwise, we can compromise important tasks and let the project unfinished without getting to solve the posed question or problem.
- Materials. Laboratory materials deserve especial attention, as it is important that students know them in advance, and learn the related vocabulary related, so that they can work and express themselves in the lab context.
- Tasks. There must be included pre-tasks to introduce the topic, outline the project and pose the driving question, information gathering and an initial discussion to plan the experimental work and define its objectives, experimental work can itself be divided in multiple tasks so that making it more approachable, creation of artifacts, presentation of results and final summary and wrap-up activities.

3.1.9. Manage the process

(i) Activate prior knowledge

Activating prior knowledge aims at connecting the previous ideas on the topic with new content. Thus, prior knowledge serves as a foundation or scaffolding where upon which they can place new facts, ideas, and concepts. In this way, they build upon the schema that they already have developed.

Activation of prior knowledge can be as easy as beginning the lesson with questions to establish what learners already know or can be based on more complex activities, such as working in brainstorming or think-write-share activities, discussing in a debate on key ideas that will be addressed in the lesson, complete a warm-up activity that set up the scene, providing partial information in visual organisers that the students have to complete, work on a word bank with new and old vocabulary, etc. In the case of CLIL-based science projects, it can have a multiple aim:

- Engage students in the project. The driving question itself might not be sufficient to keep students engaged in a complex enquiry process to complete the project, so this type of activities can serve to call their attention on the topic. The use of real-world material, such as videos, documentaries or breaking news as introductory materials can serve to connect their previous ideas while introducing new content, and, at the same time arouse their curiosity. These can also serve as first-hand testimonies to connect with global topics as active citizens while being a realistic contact with language.
- Explore their previous ideas. Teacher can take the opportunity to explore what students really know about the topic and take hints on how involved they are or they can be. As a result, teachers can revisit the following parts of the topic to make it more fruitful and worthy.
- Present the new vocabulary while reviewing the old one. This can be used as a scaffolding strategy for language learning. Presenting the scientific vocabulary that students will need to complete the project in advance can facilitate the project development, as students need the correct tools to communicate and effectively and work in collaboration during the project.

Table 2. Examples of tasks that can be implemented in projects.

Examples of Project tasks		
Descriptive Research	**Analysis**	**Decision Making**
Locate reliable information Google search Observation Books **Collect and organize of information** Reading and noting Interviewing Categorizing information Fact storming Sorting and labelling looking for similarities and differences **Synthesizing information** Drawing or graphing new ideas Sequencing information Organizing the parts into a cohesive report Collection, organization, and evaluation of information Evaluating the work of others	**Analysing results** Discussions Seminars Debates Error analysis **Operational analysis** Finding out how something works Increasing the efficiency of a process Make schemas of an experimental process **Semantic feature analysis** Mapping words, concepts, central ideas **Cost-benefit analysis** **Comparing/classifying** **Critiquing/arguing**	**Applying decision-making strategies** **Generating decision criteria** **Resolving disputes, negotiating, compromising** **Testing solution ideas** **Solving moral dilemmas, relational problems**
Hypothesis Testing	**Problem solving**	**Creating products**
Data collection **Generating hypotheses** **Experimentation** Controlling variables Processing data Analysing results Comparison of products or processes	**Interpreting clues** **Identifying problems** **Seeking solutions** **Generating ideas** **Trying out solutions** **Evaluating solutions**	**Extracting the main ideas** **Structure the information** **Make schemas** **Include visuals** **Create a presentation**

Adapted from Buck Institute for Education (2012)

- Set-up the scene for the experimental work. Working in a real experiment is usually engaging for students, as they work in manipulative task (not just passive receivers), change the pace of the lessons by get out of the classroom to work in a new scenario…so setting the experiment from the beginning can be an extra piece of motivation for them. Presenting the experiment is also a way to mind the focus.

(ii) Plan scaffolding strategies

Scaffolding is "the temporary assistance by which a teacher helps a learner know how to do something, so that the learner will later be able to complete a similar task alone" (Gibbons, 2002, p. 10). In CLIL context scaffolding is even more important since students need to process and express, sometimes, complex ideas in an additional language. There are a plethora of scaffolding strategies (activating prior knowledge, is by itself one of them) that can be especially useful in a CLIL context where students have a limited domain of the language. Here there are some examples:

- Use the register of language used by students.
- Provide language support immediately, as it is needed.
- Simplify language as much as possible without sacrificing the cognitive challenge, for instance, by shortening sentences, avoiding the use of synonyms when referring to key terms, etc.
- Place notes in the margin.
- Break materials into chunks.
- Use graphic organizers such as Venn diagrams, tables, schemas, mind maps and charts.
- Reduce the number of tasks one gives to a student at one time.
- Highlighting the most important text in a passage.
- Have students develop their own definitions for terms.
- Use pictures and realia.
- Giving clues and asking follow-up questions.
- Use analogies
- Mnemonic devices: catching sentences, phrases or jingles.
- Use strategies in teacher talk, such as repeating, recasting, etc.
- Use questions to extend or reformulate student's reasoning and create more complex connections and engage them in the investigation process.

(iii) ***Health and Safety considerations***

Before entering to a laboratory, students must be prepared and warned on possible risks associated to laboratory work. This is not only valuable in order to carry out the experiment, but as part of their lifelong learning. It can be worth devoting a session to explain safety considerations and risks associated to lab work, making sure that students clearly understand them, and that language is not a limiting factor. It can be useful to hang a poster with detailed instructions with general laboratory conduct and safety rules, in both English and Spanish. Risks can be general or particular to a type of experiment (both of them must be thoroughly explained in advance):

As general risk and safety considerations, we can include (Kostic, 1997):

- Never eat, drink, or smoke while working in the laboratory.
- Read labels carefully.
- Do not use any equipment unless you are trained and approved as a user by the teacher or supervisor.
- Wear personal safety equipment, such as gloves, glasses or face shields when working with hazardous materials and/or equipment.
- Always wear appropriate gloves when using any hazardous or toxic agent.
- When handling dangerous substances, wear laboratory coats, and safety shield or glasses. Shorts and sandals should not be worn in the lab at any time.
- Keep long hair tied back or confined.
- Keep the work area clear of all materials except those needed for work.
- Students are responsible for the proper disposal of used material if any in appropriate containers.
- If leaving a lab unattended, turn off all ignition sources and lock the doors.
- Never pipette anything by mouth.
- Clean up your work area before leaving.
- Wash hands before leaving the lab and before eating.
- Locate emergency exit and follow the evacuation plan in case of accident. Follow the instructions of the supervisor and maintain the group together.

In addition, each type of experiment have associated some particular risks, so it is necessary to carry out an analysis of potential risks, which must been clearly stated to the students. Among them, we must consider:

- Risks associated to the use of dangerous reagents. Students must understand the risks labelling. It can also imply mixing components properly, incompatible reagents
- Risks associated to the use of lab materials, such as cuts, injuries, burns, splash, etc.
- Risk associated with the use of particular equipment and tools, which may require ventilation, working in ventilated hoods, etc.
- Need of particular safety equipment, such as gloves compatible with the reagents used, use of protective glasses, etc.

(iv) Anticipate to possible challenges and pitfalls

Laboratory experiments does not always develop as it is planned because of uncontrolled variables, students are not trained in lab experiment so they can miss part of the procedure, fail in following the recipe, etc. In such cases, it could be advisable to have the material prepared in advance (i.e. the final result of the experiment) or the teacher carry out the experiment as a demonstration. It can also be useful to have pictures, videos or any material found on the Internet that work as a demonstration in case the experiment cannot be completed properly.

As the project is usually open-ended and it relies on the capacity of students to solve problems and work autonomously, there are other possible pitfalls that may arise such as the lack of time to finish the project, the need of extra support or unplanned questions that need to be solved for completion of the tasks, extra scaffolding to cover language needs, interesting topics that might arise to satisfy students' curiosity, etc. Due to this, teacher must be prepared with supplementary material, in the form of webpages, documentaries, extra activities or extra language support, to satisfy all the project requirements.

4. Discussion

The next steps in PBL would be project implementation in science subjects. Thus, it can be worth exploring what it can be expected to achieve by means of CLIL implementation in project-based learning in the scientific laboratory. The idea is to consider which common aspects can be found between CLIL and PBL and see how providing a real context in lab experiments can be the arena for meaningful learning.

Each of these common aspects will be commented in detail:

(i) *Promotion of critical thinking*

Lab experiments offer unique opportunities to the students to develop their cognitive skills by means of hands-on activities and the discovery of new learning using their critical thinking. In fact, students have to complete a task where they are intellectually challenged to transform information, solve problems, discover phenomena. During the development of an experimental task, students has to be cognitively challenged, so that they have to make use of different thinking skills, such as analyzing, comparing, organizing, guessing, evaluating and applying.

(ii) Fostering creativity and autonomy of students

Lab experiments should also be designed so that there is room for creativity. The experiment should be presented in such a way that students, so students have the chance to go above and beyond, being able to reformulate the problem, play around with variables, or predict results, rather than being mere observers who follow a recipe and answer a series of given questions.

The experimental nature of scientific subjects can help to develop creativity and self-guided learning of students. In fact, lab experiments demand a certain degree of student´s autonomy to solve a task, which might pose a challenge to the student, who has to make good use of the materials provided and their own thinking strategies to get to a final solution. This does not necessarily mean that it cannot be guided by the teacher or carried out in groups as a collaborative task.

The challenge for teachers in this sense is not negligible: just to mention some aspects to take into account, he/she must adapt the task to the age, maturity and prior knowledge of students, cater students with the appropriate scientific vocabulary and for basic interpersonal skills (i.e., follow instructions/ask answer questions, make statements), set up the appropriate objectives, consider practical aspects such as timing, materials, safety, or possible pitfalls of the experiment, design the experiment, provide the correct materials and tools for solving the problem, formulate the correct questions to guide students through learning, maintain students engaged through the activity, develop scaffolding strategies to activate critical thinking, ensure that the students are able to analyze the results, extract the conclusions and find an application, among others.

(iii) *Collaborative learning*

Collaborative learning involves communication among peers and with teacher. Thus, it offers unique opportunities to foster the use of the target language or second language (L2). The lab is a collaborative space, which provides an environment out of the regular classes, and calling for a more relaxed ambient, where students can exchange ideas, collaborate with partners, use language with freedom, and experiment with resources to approach to the goals. This can be achieved by placing learners in situations that require authentic use of language in order to communicate (e.g., being part of a team or interviewing others) in situations such as planning, organising, negotiating, arguing, and distributing tasks.

(iv) *The use of language in laboratory sessions*

Hanesová (2014) highlight the promotion of language in CLIL as a results of: "encouraging learners to produce spoken or written output helping them to think through ideas, to express them, to share knowledge, to give feedback, review ideas, to adapt and refine ideas and to negotiate solutions" (p.35). We can apply this same concept to lab activities, by different means. With regard to written productions, laboratory sessions usually end up into a final report. Laboratory reports are valuable tools that allow students to use complex language structures, improve their literacy in a specific scientific genre and create more elaborated and better organized productions than in oral interaction

In the oral production and comprehension, we should differentiate between two different interactions that may arise in the activity:

- *Student-student interaction***.** Bearing in mind the collaborative nature of lab experiments, students are in constant need of dialoging, negotiating, and collaborating with their counterparts. The subsequent risk of this is that the need to achieve a goal in the task-based activity might disregard the use of the language and sometimes derive into L1. This forces teachers to constantly supervise students' interaction so as to ensure productive conversations.
- *Student-teacher interaction*. One example can be the use of productive questions that develop learner's thinking skills. Cameron & McKay (2010) in their methodology of creative teaching also underline the role of problem-solving tasks and open-ended questions such as "*Why*…" or "*How*…". By these questions, students are cognitively challenged while they are forced to use the language. Teachers should encourage students

to develop arguments, not limiting to yes/no questions but trying to go deeper and force students to use complex structures and content-related vocabulary. Thus, the benefit of dialoguing is double: create the need of using the language to solve a problem in a collaborative ambient and to put in practice subject-related vocabulary and concepts.

(v) *Multiple intelligences and learning Styles*

The design of projects should be carried out taking into account students' interests and different learning styles, so that they get engaged in problem solving and in creative production. Thus, projects aim at assisting students in succeeding within the classroom and beyond, by developing all of their intelligences to make learning a part of living. The theory of Multiple Intelligences offers eight ways of teaching and learning styles (Bas, 2008). In this regard, teachers can ensure they provide enough variety in the activities to cater multiple intelligence and learning styles.

Traditional education places too much emphasis on mathematical and linguistic intelligences. This can create frustration for people who are comfortable with less traditional learning modalities, such as kinaesthetic, visual, interpersonal, intrapersonal, musical, or naturalist. Project based learning allows teachers to incorporate numerous teaching and learning strategies into project planning and implementation, as it is based on experiential education. Experiential education does not only focus on mathematical and linguistic intelligence but on the diverse intelligences suggested by Howard Gardner (Bas, 2008). As long as science experiments are a process of learning through experience, they can cater for students' multiple intelligences. There are several opportunities to foster the eight multiple intelligences proposed by Gardner during a scientific project:

- *Linguistic-Verbal Intelligence:* Write a scientific report with the results of the experiment.
- *Mathematical-Logical Intelligence:* Create a graph or chart with experimental results that help to analyse them and extract conclusions.
- *Spatial Intelligence:* Make a model or a drawing of the material used in the lab.
- *Interpersonal-Social Intelligence:* Present the results to the rest of the class in a final session, providing/receiving feedback from the rest of the class.
- *Personal Intelligence:* Individually reflect on the impact of the topic on their lives.

- *Kinaesthetic Intelligence:* Work out the manipulative dimension by performing an experiment in the lab.
- *Musical-Rhythmic Intelligence:* Listen to a song that deals with an environmental issue in the target language.
- *Naturalistic Intelligence:* Look for evidences (real or on the Internet) on how the topic impacts on the environment and how to develop environmentally friendly behaviours.

(vi) <u>*Lifelong learning*</u>

One of the benefits associated to the "learning by doing" dimension of experiments is that the learning acquired through experience is meaningful and durable and most of the content and skills learnt by experience are more easily transferable to real world. As part of the lifelong learning that can be acquired through using CLIL in PBL experiments we can mention learning and using language for effective and purposeful interaction, acquiring safety and clean conduct in a lab, extrapolating the experience to physical phenomena taking place in nature, being conscious of the environment and learn environmentally friendly habits, learn to work in cooperation and value the abilities, thoughts and ideas of others, accepting peer assessment as constructive opinions that can be helpful for personal growth, gain confidence in working independently and in presenting results publicly, etc.

5. Conclusions

The integration of content and language in CLIL calls for a real context to learn and use the language for meaningful learning. In fact, language learners can benefit of using the learning in real situations such as content learning in non-linguistic subjects, thus emphasizing meaning over form, and giving importance to effective communication rather than to accurate language use. In this sense, the use of CLIL in science subjects is not new, partly due to the added value of the acquisition of scientific language, with its particularities in genre, norms and vocabulary. Acquisition of scientific language is part of their lifelong learning, especially if it is linked to a real use, such as lab experimentation. In fact, scientific laboratory is a unique scenario for using the language in real situations while learning and applying scientific concepts, but scarcely exploited up to date. In this research we have analysed the potential benefits of using the scientific laboratory as a perfect set up for CLIL implementation, as it provides a "learning by doing" dimension for active learning and a real world connection through a first-hand experience of scientific phenomena.

Therefore, in lab experiments students are engaged in an inquiry process, while developing cognitive skills necessary to take measurements, collect and process data, describe results, conclusions and evaluate the results. Furthermore, the scientific laboratory is a unique scenario to use the language in a variety of situations, such as to cooperate with peers to distribute tasks, to discuss the results or negotiate the meaning, read a recipe or an experimental protocol in the target language or write a final report, not to forget the importance of using scientific vocabulary in the appropriate context.

Once the "why" has been stated, the next question to solve is how to carry out implementation of CLIL, exploring and comparing different situations for the use of laboratory experiments in learning contexts. The most extended approaches can be classified in task-based learning, project-based learning (PBL), and inquiry problem solving or inquiry-based learning (IL). Whereas task-based learning is the most widespread approach, it is not a real inquiry, as students are not expected to carry out investigations by themselves, but just following a recipe to reach a well-defined end. On the other hand, inquiry-based learning can provide more opportunities to develop high-level learning skills, as students are involved in real investigations with an open-ended end but, contrarily, can make students feel overwhelmed by too much cognitive demand and the use of new concepts, unfamiliar laboratory equipment, and novel problem-solving tasks. Project-based learning is, somehow, a trade-off, more complex and more demanding for students than TBL, but with a more active role from the part of teachers than in IL, who have to carefully plan and anticipate to project development, while students are involved in active learning on worthwhile scientific questions that clearly make a difference in their lives or in the world.

The best approach to use in lab experiments will depend, however, on particular aspects, such as timing, prior knowledge or students' age. Nevertheless, in this study the use of PBL in CLIL-based experiments is hypothesized. As previously stated, CLIL and PBL share many common aspects, which are necessary or, at least desirable requisites of meaningful learning experiences. As a defining point of CLIL, content provides a context for learning and using the language. The integration of content and language is more fruitful if the learning experience is anchored to real life applications and involves the use of cognitively demanding tasks. PBL is the ideal approach to provide real life applications to learning experiences, while putting students at the center of learning, as active learners.

Moreover, scientific projects can be designed to take into account the 4Cs framework as the common perspective for CLIL implementation. Whereas content is always the common thread in the project and it can be planned in terms of concepts, processes and attitudes, it is always linked to cognition when planning the outcomes from a cognitive point of view. In fact, cognition must be view as a progression from low to high order thinking skills through all (or some of) the categories defined in Bloom's revised taxonomy. The culmination of the project in the creative production of an artifact perfectly fits with the top of the taxonomy, thus, students have to make use of their new learning to create a final product, which, desirably, is to be presented in a communicative final task. With regard to communication, the collaborative dimension of projects leads to multiple opportunities of using the language in a real context. For a well-planned CLIL project, the three dimensions of the language –language of, for and through learning– must be considered. Thus, students will learn the scientific language to be applied in different contexts such as writing a scientific report or a lab notebook, make a presentation, read and follow a procedure in an experiment or a scientific article, share ideas or argue about scientific facts, among others. Finally, with regard to culture, which is usually the most difficult aspect to integrate, it is facilitated by both the different perspective provided by the use of a second language –which, in the case of English, is the language of science– and the real world connection provided by Science, which can be exploited to consider environmental issues and their impact throughout the world. Not to forget the value of civic learning as a way to strengthen students' civic consciousness and help them develop an appreciation of their potential impact on society and environment.

In this study we hypothesize that acquisition of both language and content might benefit of implementing PBL in the scientific laboratory. With this aim, the common aspects of CLIL and PBL applied to science laboratory have been outlined, namely: (i) the promotion of critical thinking, which appears to be essential for language and content acquisition, (ii) fostering creativity and autonomy of students, as part of their cognitive development, (iii) collaborative learning, for problem solving by effective interaction, (iv) extensive use of the language in multiple and varied situations, but in a realistic context, (v) promotion of multiple intelligences to cater different learning styles and preferences, and (vi) lifelong learning as a consequence of the learning by doing and real world application of the acquired knowledge.

6. Future research lines and limitations

6.1. Future research lines

Once the implementation of CLIL in PBL experiments, the next steps of this research will be to apply them to a real situation so as to evaluate:

- Students' view, in order to evaluate their implication in the project, the demands of completing the project due to the problem-solving nature of it, the difficulty in the last creative step, their exploitation of the lab environment for the use of the language, and possible points that need for improvement from their perspective
- Teachers' view, which can be useful to improve the project design, as part of the assessment of the project, and detect actual pitfalls in project implementation.
- Find objective parameters that determine if the potential benefits here hypothesized are reached in practice. These parameters can be based on students' achievements in content, language progression, results in the creative final task by means of the artifacts, among others. Nevertheless, it could be worth exploring whether language benefits of providing a real context based on experimental learning, and if content acquisition is somehow limited by the use of the L2 or their more active roles for project completion.
- Put more emphasis in teachers' coordination, taking into account the language teachers' perspective, and how this coordination can be carried out from a practical point of view. It can be worth including language support in language subjects that might facilitate project development. Build cross-curricular links with other subjects can also be worth considering.

6.2. Limitations

On the other hand, it is necessary to plan in advance possible shortcomings of the implementation of CLIL in PBL based scientific laboratory in secondary education, as there are some aspects that can be challenging, especially if students are not familiarized with working in a lab:

- The difficulty to relate abstract concepts in Chemistry with their lives, i.e. the motivational dimension.

- The previous knowledge of the subject can be limited. Some concepts in the subject are completely new for the students. This can be specially challenging if students do not dominate the scientific methodology, for instance, to express data, analyze results or extract conclusions.
- The use of specific vocabulary in L2. Learning chemistry involves using properly new content that can be confusing. This task can be more challenging if students do not master the L2. Language should be promoted in such a way that students do not feel intimidated by using the L2, for example, in a collaborative task.
- Students must know the risks of working in a lab environment. Teacher must consider health and safety aspects while planning the lab session and students must completely understand all these aspects. If experiment poses any risk to the students or is not adequate to their age, it might be discarded or adapted.
- Developing a project can fail if it is too demanding, so that students feel discouraged. Project design should be flexible enough so that it can be adapted to all the learning paces and to overcome any difficulties by adapting the materials or tasks to less cognitively demanding.

7. References

Anderson, J. R., Reder, L. M., & Simon, H. A. (1996). Situated learning and education. *Educational researcher*, *25* (4), 5-11.

Bas, G. (2008). *Implementation of Multiple Intelligences Supported Project-Based Learning in EFL/ESL Classrooms*. Non-published material. Retrieved on 4th February 206 from: http://eric.ed.gov/?id=ED503870.

Beckett, G. H. (2006). Project-based second and foreign language education. *Project-based second and foreign language education: Past, present, and future*, 1-15.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational psychologist*, *26* (3-4), 369-398.

Buck Institute for Education (2012). *Project tasks*. Non-published material. Retrieved on 20th February from: http://bie.org/objects/cat/planning_forms.

Cambridge, V.A. (2011) *Teaching Science through English- A CLIL approach*. University of Cambridge ESOL. Non-published material. Retrieved on 26th October 2015 from: https://www.researchgate.net/file.PostFileLoader.html?id=560123f95e9d97b5a28b457b&assetKey=AS%3A276421046173698%401442915321347.

Cenoz, J. (2015). Content-based instruction and content and language integrated learning: the same or different? *Language, Culture and Curriculum*, *28* (1), 8-24.

Cobern, W. W. (1991). Contextual Constructivism: The Impact of Culture on the Learning and Teaching of Science. *Paper presented at the Annual Meeting of the National Association for Research in Science Teaching* (Geneva, WI, April 7-10, 1991).

Committee on Science Teaching (2007). Goals for Science Education. In: Duschl, R. A., Schweingfruber, H.A. (Eds.), *Taking Science to School: Learning and Teaching Science in Grades K-8 (*p. 37*)*. Washington D.C.: National Academies Press.

Coyle, D. (2005) Developing CLIL: Towards a Theory of Practice, APAC Monograph 6, Barcelona: APAC.

Coyle, D. (2007). Content Language Integrated Learning: Towards a Connected Research Agenda for CLIL pedagogies. *International Journal of Bilingual Education and Bilingualism,* 10 (5), 543-562,

Coyle, D., Hood, P., & Marsh, D. (2010). The CLIL tool kit: transforming theory into practice. In: Coyle, D., Hood, P., & Marsh, D., *CLIL: Content and Language Integrated*

Jarret, D. The Inclusive Classroom. Teaching Mathematics and Science to English-Language Learners. Oregon: Northwest Regional Educational Laboratory

Cummins, J. (1983). Language proficiency, biliteracy and French immersion. *Canadian Journal of Education*, 8, 117–138.

Dalton, S., & Sison, J. (1995). *Enacting instructional conversation with Spanish-speaking students in middle school mathematics*. Santa Cruz, CA: National Center for Research on Cultural Diversity and Second Language Learning (pp. 1-23). Retrieved on 13th December 2015 from: http://eric.ed.gov/?id=ED382030.

Domin, D. (1999). A Review of Laboratory Instruction Styles. *Journal of Chemical Education,* 76 (4), 543–547.

Escobar, C., & Sánchez, A. (2009). Language learning through tasks in a Content and Language Integrated Learning (CLIL) science classroom. *Portal linguarum, 11,* 65-83.

Fay, M.E., Grove, N.P., Towns, M.H. and Bretz, S.L. (2007). A Rubric to Characterise Inquiry in the Undergraduate Chemistry Laboratory. *Chemistry Education Research and Practice* 8(2), 212–219.

Giouroukakis, V., & Connolly, M. (2013). Chapter 2: The Benefits of the CCSS for the Teaching of Reading in the Content Areas. In: Giouroukakis, V., & Connolly, M., *Getting to the Core of Literacy for History/Social Studies, Science, and Technical Subjects, Grades 6–12*. (p. 25) California: Corwin Press.

Giouroukakis, V., & Rauch A. (2010). Science for the English Language Learner: Strategies to Enhance Comprehension. *Educators´ voice*, III, 50-55.

Grant, M. M. (2002). Getting a Grip on Project-based Learning: Theory, Cases and Recommendations. *Meridian: A Middle School Computer Technologies Journal* 5 (1), 1-3.

Grant, M. (2009). Understanding projects in project based learning: A student's perspective. *Annual Meeting of the American Educational Research Association, San Diego, CA*.

Hanesová, D. (2014). Development of Critical and Creative Thinking Skills in CLIL. *Classroom Research in Pre-Service Teacher Training: A Case Study*, *2*, 33.

Hedge, T. (1993). Key concepts in ELT. *English Language Teaching journal*, *47*(3), 275-277.

Krajcik, J.S., Blumenfeld, P.C (2006). Project-Based Learning In: Sawyer, R.K. (Ed). *The Cambridge Handbook of the Learning Sciences* (pp. 317-335). Cambridge: Cambridge University Press.

Kostic (1997) *General Laboratory Safety Procedures And Rules*. Non-published Material. Retrieved on February 2nd 2016 from: http://www.kostic.niu.edu/labsafetyrules.html.

Gregorczyk, B. (2012). An empirical study on the acquisition of content in a CLIL-based chemistry course: A preliminary report. *Latin American Journal of Content & Language Integrated Learning*, *5* (1), 9-32.

Gibbons, P. (2002). Scaffolding Language and Learning. In: Price, H.K. (Ed.) *Scaffolding language, scaffolding learning: teaching second language learners in the mainstream classroom* (pp. 10-19). Portsmouth: Heinemann.

Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into practice*, *41* (4), 212-218.

Laplante, B. (1997). Teaching science to language minority students in elementary classrooms. *New York State Association for Bilingual Education Journal*, 12, 62-83.

Medina-Jerez, W. (2008). Between local culture and school science: The case of provincial and urban students from eastern Colombia. *Research in Science Education*, *38*(2), 189-212.

National Research Council (1996). *National Science Education Standards* (p. 23). Washington DC: National Academy Press.

Novak, J. D., & Linn, M. C. (1977). Scientific reasoning: Influences on task performance and response categorization. *Science Education,* 61 (3), 357-369.

Quinnell, R., Hibbert, D.B. and Milsted, A. (2009). eScience: evaluating electronic laboratory notebooks in chemistry research. *Proceedings Ascilite, Auckland,* 799–803.

Ravitz, J., Mergendoller, J., Markham, T., Thorsen, C., Rice, K., Snelson, C., & Reberry, S. (2004). Online professional development for project based learning: Pathways to systematic improvement. *Association for Educational Communications and Technology Annual Meeting*. Chicago, IL.

Real Decreto 126/2014, de 28 de febrero, *por el que se establece el currículo básico de la Educación Primaria*. Boletín Oficial del Estado, 52, de 1 de marzo de 2014.

Reiser, B. J., Krajcik, J., Moje, E., & Marx, R. (2003). Design strategies for developing science instructional materials. In: *annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA*.

Sage, S. M. (1996). A Qualitative Examination of Problem-Based Learning at the K-8 Level: Preliminary Findings. *Annual Meeting of the American Educational Research Association*, New York.

Snow, M.A., Met, M., Genesee, F., 1989. A conceptual framework for the integration of language and content in second/foreign language instruction. *TESOL Quarterly,* 23, 201– 217.

Stoller, F. (2002). Project work: A means to promote language and content. In: Richards, J.C., Renandya, W.A. (Eds.). *Methodology in language teaching: An anthology of current practice* (pp. 107-119). Cambridge: Cambridge University Press.

Tardieu, C., Dolitsky, M. Chapter 1 : Impact of the CEFR on CLIL : Integrating the task-based approach to CLIL teaching. In : Martinez Agudo, J.D. (Ed.), *Teaching and Learning English through Bilingual Education* (pp. 1-32). Cambridge : Cambridge Scholars Publishing .

Thomas, J. W. (2000). *A review of research on project-based learning (*Thesis). The Autodesk Foundation, California. Non-published material. Retrieved on 12th December 2015 from: *http://www.bie.org/index.php/site/RE/pbl_research/29*

Tibaldi, E. V. (2012). The scientific laboratory as a learning setting in CLIL. *Synergies Italie, 8, 175-186.*

Tracy, L., Abd-Hamid, N.H. (2006). Making Science and Inquiry Synonyms. In: Yager, R.E. & Enger, S.K. (Eds.), *Exemplary Science in Grades PreK-4* (pp. 131-142). Arlington: NSTA Press.

Universidad Internacional de La Rioja (2015). *Curriculum Planning. Unit 11: Project-Based Approach in CLIL Curriculum Planning* (p.4). Non-published material.

UNSW, 2015. *Assessment Toolkit. Assessing Laboratory Learning*. Non-published material. Retrieved on 5th February 2016 from: https://teaching.unsw.edu.au/assessing-laboratory-learning

Veermans, M., & Järvelä, S. (2004). Generalized achievement goals and situational coping in inquiry learning. Instructional Science, 32 (4), 269-291.

Vincent, T. (2014). *Crafting questions that drive projects*. Retrieved on 12th January 2016 from: http://learninginhand.com/blog/drivingquestions

Yassin, S. M., Tek, O. E., Alimon, H., Baharom, S., & Ying, L. Y. (2010). Teaching science through English: Engaging pupils cognitively. *In Depth*, 3 (4), 5.

Zumbach, J., Kumpf, D., & Koch, S. (2004). Using multimedia to enhance problem-based learning in elementary school. *Information technology in childhood education annual*, 2004 (1), 25-37.

21st CCLC, 2014. *Civic Learning and Engagement*. Non-published material. Retrieved on 14th January from: https://y4y.ed.gov/learn/pbl/introduction/civic-learning-and-engagement/