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## The **A-B-C** of Content Learning in CLIL Settings

# The Teaching and Learning of **Science** in Secondary **Education**



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**1**

**What is the main purpose of teaching and learning non-CLIL as well as CLIL Science in compulsory and post-compulsory education?**

Learning science means learning in the most fundamental way about the world around us- science is in the air that we breathe, the water that we drink or bathe in, the food that we eat, the rocks that form our streets and sidewalks, and the seemingly still and silent stars of the night sky without whose birth, existence and death, no life on Earth could ever have existed. Scientifically-derived technological instruments are ever-present in our lives: cell phones, hybrid cars, GPS, I-pads, microwave ovens, MRIs and TACs. Science is present in the processes that lead to the cure of a breast cancer, as well as in the over-exploitation of our natural resources for fuel. Science is culture. We see and hear about science on the news, in newspapers, on television, in hospitals, in museums or in Wikipedia. Despite the commonplace idea to the contrary, the scientific endeavour

is not a search for the truth, but rather a quest to understand how the world around us operates.

Science, politics and religion propose diametrically opposed approaches to the epistemological and ontological understandings of our world. Yet in so many regions the questioning of the validity of scientific reasoning brings back echos of Galileo's 17<sup>th</sup> century trial and condemnation by the Inquisition for espousing Copernicus' heliocentric theory. In a world in which political perspectives try to dominate the conversation regarding urgent global concerns- such as those of climate change, species extinction or water shortage- our responsibility as teachers is to help our students apply a scientific perspective to a controversial issue as a means to their own personal development as well as that of facilitating their future knowledge-based contributions to a healthy democracy. Upon being forced to recant that the Earth revolved around the sun, Galileo is famously quoted as having said "E pur si muove" -and yet it moves. It is this scientific perspective- spirit, if you wish- which we as teachers must aim to foster in our students.

## 2

How do **current approaches** to the teaching and learning of Science differ from traditional encyclopedic approaches?

Before Sputnik, **behaviourism** dominated the scientific educational field. In the post-Sputnik era with its concerns for the future generation of scientists, there was a great push for **inquiry-oriented scientific curricula** and a plethora of curricular materials were developed to help students learn science by doing science and by analysing scientists-in-action. However, in their aim to produce future scientists capable of innovating technologies for economic and military purposes, schools tended to ignore the relevance or the interest of students for the subject. This focus on creating an elite group of scientists and engineers for military purposes has led to problems of equity in science teaching and learning with which we are still dealing today.

As for current approaches, for the past four decades a “**conceptual change model**” has dominated the scientific educational field. This model states that “students attend science classes with pre-instructional knowledge or beliefs about the phenomena and concepts to be taught, that these constructs are deeply held, and that they are frequently not in harmony with scientific views. (Treagust, 2006: p. 25) In order to learn new constructs, the student must actively and intentionally replace the prior scheme with a new model; in other words, the learner must undergo a “conceptual change.”

The **social constructivism** model which adobes for communication and interaction among all actors in the learning process has been proposed as one of the most adequate means by which to promote conceptual change and knowledge acquisition. Scientific classrooms no longer resemble libraries. They are dynamic spaces where students propose, discuss, question, analyze, model, simulate, debate and defend, to name just a few of the myriad actions by which science learning takes place.

Lastly, a book named *Science for All Americans* by Rutherford and Algreen in 1990 has had a major impact on science curriculum reform, though more so in North America than here in Catalonia. Rutherford advocates a “**Less is more**” principle which emphasizes the learning of ideas and thinking skills over the acquisition of long lists of specialized lexis and memorized procedures. The curriculum is simply too long. Rather than attempting to cover all topics, the less-is-more principle calls for a small, representative set of topics to be studied in detail so as to promote basic scientific literacy. Specific details would then serve as enhancing elements. All science teachers with whom the author has exchanged opinions agree that it is impossible to cover all aspects of the curriculum. Rutherford’s model points us in the direction of a how to design our lessons and planning so as to achieve quality science learning for our students.

## 3

What **role** does **language** (I.E. oral interaction, reading and writing) play in the teaching and learning of (non-CLIL as well as) CLIL Science?

Before answering this question, let us briefly examine the double challenge faced by students attempting to acquire a scientific lexis. First, the terminology is often *opaque*. By this we mean that scientific lexis translations into the L1 do not, in many instances, serve as a means to understanding the term itself. Students continually ask how to translate terms- such as lymphatic, accretion, nebula or bronchitis- into Catalan or Spanish, only to be uniformly disappointed by the answer they receive. These are not terms in the everyday parlance of our students. Secondly, scientific lexis is *dense*. By this we mean that the concepts inherent to a single word, such as heat or gene, both terms familiar to students in their L1, are multi-layered and often require critical thinking skills to be completely understood.

Given the difficulties of *opacity* and *density* in scientific lexis and concepts, interaction involving language between students becomes a building block upon which understanding is constructed. In accordance with the concept change model, students need to expose and reject any alternative or erroneous preconceptions they may have concerning a particular topic. Studies show that this is not a one-time process; contradictory scientific conceptions on a particular topic may be held by students despite evidence rejecting one of the alternatives. The newly acquired knowledge needs to be explored and explained from many different angles in order for the new concept to become firmly consolidated in the student’s mind.

Science has its own genres and academic register, as discussed in question 8. Beyond these typical scientific text types, all different forms of texts may be used in the teaching and learning of science to spark students’ interest and further their understanding including writing newspaper articles, preparing brochures, composing blogs, etc. The same may be said for the oral register where role-playing, radio journals or between-country *Skype* exchanges could be employed.

There is a place, then, for all forms of passive and active language use in a science classroom, but if this were a beauty contest, interaction between peers would surely win the prize.

## 4

May the teaching and learning of Science **benefit** in any way **from being taught through English**, or through any additional language in general?

We often refer to English as the *lingua franca* of this globalized world. In no area is this more true than in that of science. At younger ages, students are not aware of the importance of English in the scientific field, but as they grow older, they soon realize the necessity of acquiring a high competency level in this language if they

wish to pursue a career in any science-related field. The need for acquiring English skills factors closely into student motivation which, in turn, benefits their learning. As for other languages, much to the chagrin of many advocates of plurilingualism including this author, this added motivation is specific to the English language due to its domineering effect in the international science field.

## 5

**May the teaching and learning of Science benefit from an **across-the-curriculum** approach? If so, in which way?**

**W**e tend to teach science as specific subject areas limited in scope: biology, geology, chemistry or physics. But science is much more than a knowledge of the laws which govern these disciplines. In understanding our world, the fields of mathematics and technology are key to the scientific enterprise, as is advocated in the STEM approach (Science, Technology, Engineering and Maths). So, too, is an understanding of the place in history of science and its contribution to the development of our society. Thus, an across-the-curriculum approach to doing science implies not just putting on our scientific goggles, but also interpreting our world through this much broader across-the-curriculum framework.

## 6

**Please, explain one (or two) instance of exemplary teaching strategies especially useful in a quality (CLIL) Science lesson.**

**O**ne exemplary teaching strategy is to use **analogies**. Analogies serve to make difficult concepts more understandable by using the familiar to teach the unfamiliar. Cells may be compared to schools or factories and each of a cell's organelles to a particular room, object or person related to that facility. The profoundest learning results when analogies are proposed by the students themselves after having come to a thorough understanding of the topic. **Figure 1** shows how one student dyad compared the cellular structure of lysosomes to the head of studies because both "protected us against bad things," while another dyad compared the same structure to the cleaning products of a school.

Another extremely useful strategy in any quality science lesson is that of **modelling**, both static and dynamic forms. Play dough may be used to model the processes of mitosis and meiosis, while colored cut-outs may be maneuvered to simulate protein synthesis (**Figure 2**). A group of students holding hands and knocking each other gently on the hip models the transmission of longitudinal waves through liquids with the student bodies themselves representing the material that stays in place after the wave has passed. While students do love modelling scientific concepts, for effective learning to occur it is essential that students actively process the information acquired in the model by means of tasks such as drawings, diagrams or dialogues.

## 7

**Can you provide one or two examples of **quality learning tasks** for the (non-CLIL as well as for the) CLIL Science class?**

**O**ne technique is to pass students a table with a list of terms or phrases in one column representing rich, dense concepts which will be studied in the unit. Three columns follow with the headings: "**I know how to explain this,**" "**I recognize this, but I don't know how to explain it,**" and "**I have never heard of this.**" Students *self-assess* their knowledge by marking one of the three columns for each term. Following this, students form small groups and *explain the terms to each other* using collaborative or cooperative strategies depending on the instructions of the teacher. For instance, one student who has never heard of a term may ask group members to explain it to him/her. Alternatively, a student may choose to explain one word that he/she knows well to the rest of the group. The *self-assessment can be repeated* at the end of the unit or a *co-assessment procedure* could be employed. In this second round of explanations, a student can explain a term that they could not explain previously.

This task is a mutually-beneficial activity for the strongest and weakest students in each group, as learner's often better understand a peer's explanation than that provided by a source of a more authoritative nature, such as the teacher, a textbook or a video report. At the same time, the stronger student can consolidate his/her knowledge base through specificity, examples, etc. In a focus group interview conducted by Dr. Escobar (2012), batxillerat students in a CLIL science class explained how useful this activity was in helping them become aware of the degree to which they really knew the material of the topic under study. One student said that her means of determining if she needed to study more was whether or not she was able to successfully describe a specific concept to a student who knew it less. Lastly, from the teacher's perspective this task provides individual and group information regarding the efficiency of the learning process.

## 8

**What are the main characteristics of the **disciplinary texts** that students are required to read and write in the non-CLIL as well as CLIL Science class? (genre, text typologies)**

**S**cience has its own genres and registers with which learners must become familiar. On the written level, these include lab reports, scientific articles, reporting on scientific findings, constructing hypothesis, etc. Teachers must provide numerous high-quality models and opportunities to enable students to comprehend and produce written texts in these genres. Scientific texts must be objectively descriptive and often require specific grammatical structures, such as the first conditional for hypothesis, or the passive voice to

describe results. On the oral level, scientists must learn to make presentations, describe findings and argue critically. The interplay between the visual and the written or spoken word is especially strong in science, and teachers should include lots of practice time for students to develop the skills of saying in words what a graph represents or putting into a chart what has been described in words.

## 9

**Can you provide one or two instances of exemplary tasks especially useful in the assessment of science-related key competences which could be adapted to a CLIL environment?**

In CLIL environments, it is particularly useful for students to represent in a drawing, diagram, model or other visual format the phenomenon they are observing. This visual representation should always be accompanied by a written text, but the level and complexity of that text and the amount of language support which is required depend very much on the individual characteristics of the class and of each student. Texts can range from single words to long paragraphs or even reports. The dog and accompanying text in **Figure 3** represent one example: Students drew a dog with specific traits resulting from a hands-on, paper-based activity designed to learn about genes and genomes. Following this, the students wrote one paragraph describing the physical traits of the dog, and a second paragraph with a scientific explanation of each of the traits as determined by the genes.

## 10

**How can less scholastic activities, such as dancing, pottery, drama, singing, etc., be integrated into the teaching and learning of Science?**

What is more dramatic than the ongoing debate about the validity of the theory of evolution, or the fact of climate change and how it will affect our lives? Teaching students to defend and argue for and against these positions in role-plays or debates are wonderful practise for them to work out their own arguments when confronted with seemingly untenable scientific positions. Dancing is movement as well as emotion- thus, the nervous, sensory and locomotor systems would all be perfect candidates for study. Singing is also a fascinating scientific phenomena involving the respiratory and locomotor system, as so beautifully displayed by the recently passed Montserrat Caballé. Music could also be studied from the perspective of waves, or the endorphins that are released upon hearing a concert by Chopin. Asking our students to describe how clouds form, for example, through a song activates capacities in the areas of music, science, creativity and critical thinking. Combining science with any other type of curricular subject matter should not be a cause of concern, as science is everywhere.

## 11

**Can you suggest one or two titles (books, articles, etc.) which may help a practitioner to become a better CLIL (and non-CLIL) Science teacher?**

Herr, Norman (2008). *The sourcebook for teaching science: Strategies, activities, and instructional resources*. San Francisco: John Wiley & Sons.

Rutherford, F. J., & Ahlgren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Scott, P. (2008). Talking as a way to understanding in science classrooms. In P. Scott, N. Mercer, & S.

Hodgkinson (Edits.), *Exploring talk in school*. London: SAGE Publications.

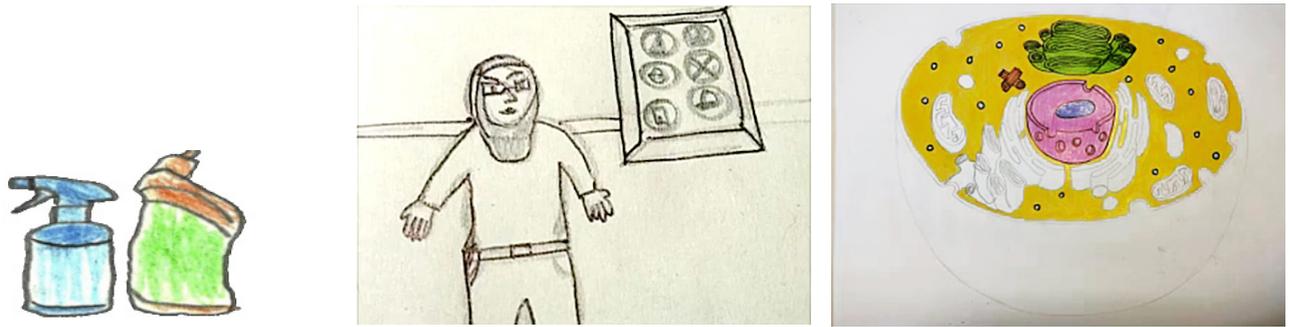
Tobin, K. ed. (2006). *Teaching and learning science: a handbook*. Westport: Praeger Publishers.

Treagust, D. (2006). Conceptual change as a viable approach to understanding student learning in science. In K. Tobin (ed.) *Teaching and learning science: a handbook* (pp. 25-32). Westport: Praeger Publishers.

## 12

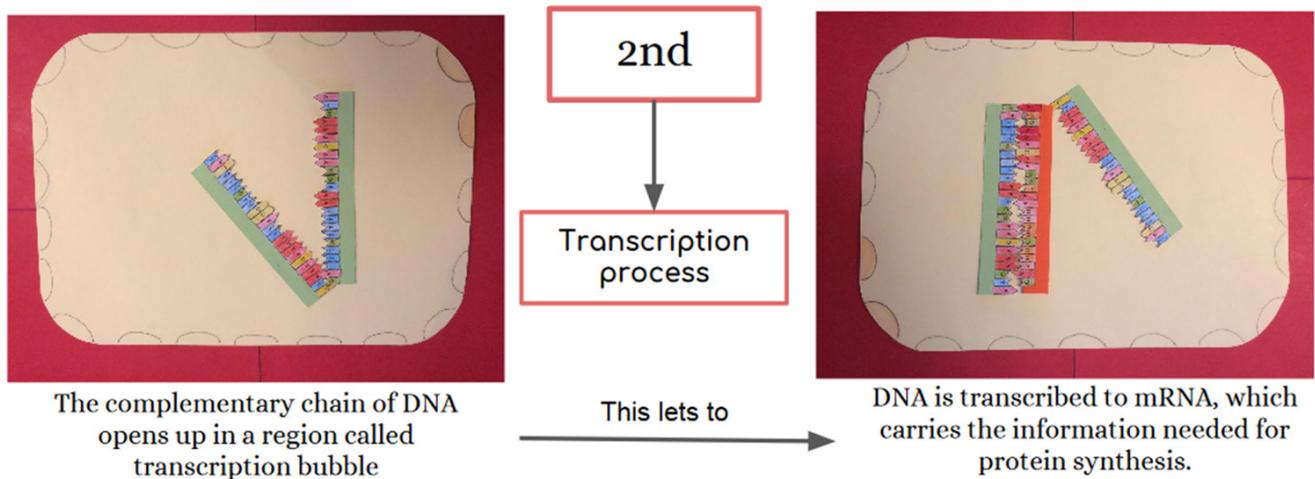
**If you hold on to any particular pedagogical, psychological, philosophical or linguistic view or theoretical framework (i.e. Behaviourism, Cognitivism, Social-interactionism) please, let the reader know the label or labels that designate it.**

In the teaching and learning of science, I highly value the quality of **classroom discourse** which takes place among my students through **collaborative and cooperative tasks**. I believe that this interaction is the key not only to their acquiring knowledge through **conceptual change**, but also to their advancement in comprehending and producing scientific genres, as these are challenging topics and often two heads are better than one. **Dynamic, hands-on tasks** contribute to the **authenticity** of this dialogue. Moreover, I understand discourse as a means of **acquiring metacognitive awareness** through **self- and peer-assessment**. From what I have described it is clear that my theoretical framework is that of Social-interactionism. ■

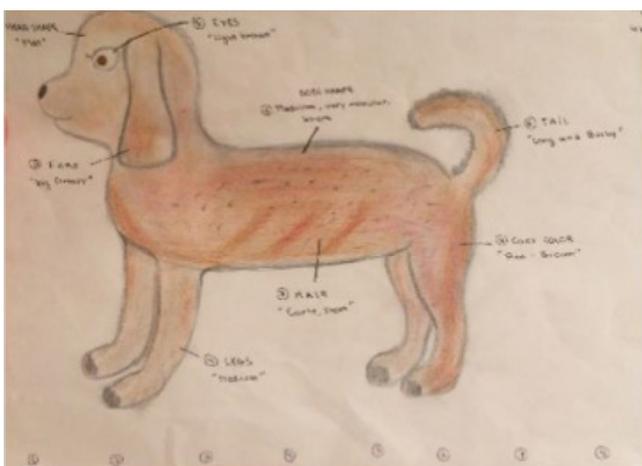


**Figure 1.** Lysosomes as analogous to the head of studies or to cleaning products.

## 2. Process of protein's creation: Step by Step



**Figure 2.** Modelling the transcription process of protein synthesis



**Figure 3.** Dog genome representation, narrative description and scientific explanation

The result was a beautiful medium sized dog who was very muscular albeit short. Although his head was flat, he could dissimulate it thanks to his big droopy ears. His legs were proportional to his body and he was characterized by his red brown coat and his curly short hair. He had also lovely brown eyes and a funny long and bushy tail. All these traits made him special and unique!

Thanks to this activity we have learnt that a genome is the set of all chromosomes of a particular species. Although our fictitious dog had only 9 chromosomes, real dogs contain about 39 pairs of chromosomes (19000 genes) and humans contain about 23 pairs (22000 genes). Each genome contains all of the information needed to build and maintain that organism and we have also learnt that each gene resides at a specific location on a chromosome in two copies, one copy of the gene inherited from each parent. The copies, however, are not necessarily the same and when the copies of a gene differ from each other, they are known as **alleles**. So, finally, we have concluded that the genes of all dogs can be different to each other but they are always ordered along the molecule the same way, that's that if the first trait determined in a dog is Body shape, all dogs will have the same trait determined in the same position.