

# **“Content and Language Integrated Learning” teaching in science: a didactic analysis of a case study**

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## **ABSTRACT**

*Our article deals with a didactic analysis of the teaching of a non-linguistic subject, physics and chemistry, in English, within the framework of “Content and Language Integrated Learning” (CLIL) programs. We describe, from the case study of a science teacher, the articulation between scientific knowledge and language knowledge. From the analysis of video extracts of a lesson about Rutherford’s experiment, we produce a description of the asynchronous advance of the different contents at stake. We propose at the end of the article recommendations for the training of teachers who teach in CLIL programs.*

## **KEYWORDS**

*Science, English, Content and Language Integrated Learning (CLIL), Joint Action Theory in Didactics (JATD), documental approach of didactics*

## **RÉSUMÉ**

*Notre article porte sur une analyse didactique de l’enseignement d’une Discipline Non Linguistique (DNL), la physique-chimie, en anglais. Nous décrivons, à partir de l’étude du cas d’une professeure qui enseigne dans ce dispositif, l’articulation entre les savoirs scientifiques et les savoirs langagiers. À partir de l’analyse d’extraits vidéo d’une séance sur l’expérience de Rutherford, nous produisons une description de l’avancée asynchrone des différents savoirs en jeu. Nous proposons en fin d’article des recommandations pour la formation des professeurs qui enseignent dans ces dispositifs (DNL, classes européennes, CLIL).*

## **MOTS-CLÉS**

*Sciences, anglais, Discipline Non Linguistique (DNL), Théorie de l'Action Conjointe en Didactique (TACD), approche documentaire du didactique*

## **INTRODUCTION**

We present a case study on the teaching of chemistry in English, at high school in France. The teaching of this “non linguistic subject” in a foreign language takes place within a specific environment in what are called “European classes” (Ministère de l'Éducation Nationale, 1992), where academic content is taught through a foreign language. These classes are based on the so-called approach “Content and Language Integrated Learning” (CLIL), which consists in the teaching of a particular subject matter in a foreign language. As Tardieu and Dolitsky (2012) put it, the main objective was to gain fluency in a foreign language.

The data have been collected as part of a national research project in France (“ReVEA”), funded by the French National Agency for Research (ANR). That's why we examine, in this paper, the didactic effects of the use, by a science teacher called Laureen, of resources for chemistry teaching in English. Besides, we cross the use of concepts that are respectively specific to the fields, i) of the didactics of science, and, ii) of the didactics of foreign languages. We will first present the context of our study and the theoretical framework; secondly, we will expose the methodological tools that have been used to answer our research questions. We will then analyse three episodes, extracted from the videos of the lessons that have been filmed, and discuss our results. We will eventually produce some recommendations for teacher training.

## **CONTEXT OF THE STUDY**

Considerable research has already been carried out about CLIL. Some studies have shown that, during CLIL lessons, the scientific knowledge is frequently withdrawn, relatively to the linguistic contents (for instance, Maitre, 2017). It also been showed that the vocabulary used during the interactions is more related to everyday speech than to specific domain knowledge contents (Auer, 1988; Caffi & Janney, 1994).

Some authors (Roussel, Joulia, Tricot & Sweller, 2017) have also demonstrated that “learning academic content through a foreign language is likely to lead to sub-optimal results” (p. 70). They have also indicated that, among the studies have been concerned with the effect of CLIL instruction on students' language skills (Jexenflicker & Dalton-Puffer, 2010; Ruiz de Zarobe, 2010), several of them have shown positive effects of this approach on linguistic outcomes (Admiraal, Westhoff & de Bot, 2006; Lasagabaster, 2008; Ruiz de Zarobe, 2008; Loranc-Paszylk, 2009; Varkuti, 2010). It is also said that “Dalton-Puffer (2011)

suggested that students have better language performance, and show more ability, accuracy, and fluency in using a foreign language” (Roussel, Joulia, Tricot & Sweller, 2017, p. 70).

Gajo (2001) has shown that learners develop specific strategies, such as “code-switching”, to maintain communication in CLIL classes. In a general way, researchers insist on the search, by teachers, for a balance between content and language knowledge (Lyster, 2007; Mehisto, 2008).

The originality of this study is to provide a didactic analysis of a teacher’s actual actions in class, and to examine the interweaving of language and scientific contents that are constructed. We describe how the teacher organizes the relationship between the selected resources and the orientation of work with scientific and language contents. We notably attempt to examine how the students are conducted to work, or not, on the language that is necessary to the understanding of scientific knowledge. We also examine, from a didactic point of view, how scientific and language contents progress in time, but not at the same pace.

## **THEORETICAL FRAMEWORK**

In this paper, we investigate how a chemistry teacher uses her resources (Adler, 2000) during a lesson on atoms which is entirely in English. We do not only consider the teacher’s resources, but also the links between her knowledge and her documentation work, using the perspective of the documentational approach of didactics (Gueudet, Pepin & Trouche, 2012).

For this study, we refer to some concepts that have been developed, in comparative didactics (notably, Sensevy, Mercier, & Schubauer-Leoni, 2000), within the framework of the Joint Action Theory in Didactics (JATD), in order to understand didactic activities (Sensevy & Mercier, 2007; Sensevy, 2011; Gruson, 2016). The JATD seeks to formulate the teacher and the students’ actions as a whole dynamic unit, using concepts that describe didactic activities as a joint structure.

In the JATD, the concepts of didactic contract and milieu help define a strategic system, which is the strategic system of teaching and learning. These concepts are closely articulated. The contract can be described as what is already known by the students, as habits that structure a system of expectations between the teacher and the students about what they have to do, and with what kind of strategies and knowledge. The milieu can be defined as what is to be known, as a problem that produces resistance to the learner’s action. The learner has to overcome this resistance by interpreting the problem in order to learn and to gain new knowledge.

We will also call “learning games” (Sensevy, 2011; Gruson, Forest & Loquet, 2012) teaching and learning situations that are “observed *in situ*, that is while the teacher and the students are playing them” (Gruson & Marlot, 2016). Sometimes, as Gruson and

Marlot put it, the learning game expected by the teacher does not happen, and a more generic game substitutes itself for the expected game: this is called a “shift in the game”.

The main difficulty in the production of learning situations is to elaborate a milieu, a problem, that resists to the learner’s action, in order to make him go beyond what he already knows, but not too much because if the milieu is too complex to decipher, to decode, the student won’t be able to learn. When the milieu appropriately resists the student’s action, learning can occur and renew what the student knows and how she knows it. We also refer to the concepts of topogenesis and chronogenesis (Chevallard, 1991; Sensevy, Mercier, & Schubauer-Leoni, 2000). Topogenesis describes the partitioning of knowledge between the teacher and the students, and chronogenesis describes the temporal progression of the knowledge at stake.

During CLIL lessons, the milieu can be difficult to apprehend (for the students) and to organize (for the teacher), because of its twofold complexity (Le Hénaff et al., 2017; Jameau & Le Hénaff, 2018), due to the diverse types of knowledge that are aimed at, sometimes simultaneously, sometimes not. We choose to mobilize the theoretical framework of the JATD, in order to produce a better intelligibility of the determinations, 1) of the teacher’s choice of resources (relative to the didactic contract, for example), and 2) of the use of these resources in action, and of its consequences on the students’ learning, in particular on the asynchronous nature of this learning.

The scientific literature on CLIL regularly draws the conclusion that subject content is lagging behind language knowledge and that this type of program is likely to overload students cognitively. Most of the time, it uses a quantitative methodology to obtain these results. To complete or clarify these results on these points, we decided to use a methodology based on a case study, based in particular on the concepts of the didactic contract, the milieu, and the triplet of genesis. The objective is to be able to describe, as finely as possible, actual practices, and to shed more precise light on the complexity of the interweaving of language and scientific knowledge.

Thus, we study, i) how the contract influences the documentational process (the selection and the use of resources by the teacher), ii) how the teacher articulates the advance of scientific and language knowledge and, notably, iii) how the teacher makes her students work on scientific vocabulary, and which scientific vocabulary, in a foreign language.

## **METHODOLOGICAL FRAMEWORK**

Our methodology is based on the “valise” methodology (Trouche, 2014), which provides methodological tools enabling us to track how the studied teacher, both inside and outside her educational institution, uses and produces her teaching resources. We followed several principles. The teacher’s work has been observed by the researchers in and out of class; a long term follow-up has been organized, during several school years.

The teacher and the researchers have worked together. This theory is associated with a specific methodology called “reflective investigation” (Gueudet & Trouche, 2008a), that has been initially applied in the field of didactics of mathematics, but also in science (Jameau, 2012). The teacher has had a reflective stance on her own work: for instance, she has provided comments on videos of her activity filmed by the researchers, during an auto-analysis interview (Jameau, 2015).

Self-analysis is considered here as a method of empirical data collection and analysis of verbal protocols in relation to action and not as a targeted training to help build professional skills. Indeed, we wish to distinguish a self-analytical interview which, in our study, focuses on the knowledge taught and on the learning of students, from a self-confrontation interview which is defined as a method of analysis of the work activity (Clot, Faïta, Fernandez & Scheller, 2001) which aims not only to understand the work to transform it, but to transform it to understand how development occurs or does not occur.

This interview has been based on the preliminary selection, by the researchers, of significant extracts of the transcriptions of the lessons. During this interview, the teacher has been asked to describe her actions and to comment on them, by making explicit what she thought or took into account in order to conduct the activities.

This approach provides methodological tools that distinguish, within a genesis process, available resources from the documents elaborated by the teachers with these resources. The purpose of this methodological framework is to design a system of tools that would allow us to track how teachers, individually, collectively, inside and outside their educational institution, use and produce their teaching resources.

Video data have been collected during the lessons. We filmed 4 lessons of 45 minutes in English, about the story of atoms. Our initial results are based on the transcriptions and synopses of these lessons, reconstructed from video recordings. Thanks to the transcriptions of the Speech Turns (ST) and to the synopses, we identified some significant episodes and examined finely how the use of resources in class could highlight the teacher’s didactic intentions. We selected episodes that obviously highlighted the problematic of the articulation between scientific and linguistic knowledge stakes. We also conducted epistemic analyses of the resources of the lessons, that is to say analyses about the knowledge at stake within these resources, relatively to the situations implemented.

Laureen has been a physics and chemistry teacher at upper secondary school for five years; she teaches with tenth, eleventh and twelfth graders. She usually teaches science in French, and she can also be considered as a proficient user of English. As her English is fluent, she also teaches science in English in a “European class”. The students attend most of their science lessons in French three times a week, and receive complementary teaching in English once a week, usually about a scientific theme that has been tackled during French lessons.

## **ANALYSIS OF THE DOCUMENTATIONAL WORK OUT OF CLASS**

### ***The teacher's preparation work***

The interviews with the teacher were conducted from 2015 to 2017. During the first interview in 2015, she had been asked by the researchers to explain how she was used to organize her usual system of resources.

She notably said that, while she prepares her lessons, she is used to search on the Internet by keywords that she identifies from the programmes of the class concerned. She uses a search engine to select resources and does not have any favorite websites. In her search, she sometimes adds the level of class to her keywords. We observe that the teacher does not save in her favorites the sites in which she downloads resources or erases them after use. She tells us to be sure to find them. Moreover, the teacher declares to save temporarily the downloaded resources. They are erased when the documents or didactical resources (a resource that has already been used in the classroom by the author) are saved in a USB key and on the hard drive of the personal computer. Laureen does not often use textbooks or colleagues' work except in the case of experimental teachings where resources are stored in a binder available in the physics or chemistry lab.

Laureen taught the atom in English four years ago. She stored her documents in a binder dedicated to teaching CLIL lessons. She begins her preparation by connecting to a colleague's website from which she has downloaded resources that have allowed her to construct documents for the class. She notes, during her preparation, that there are very few open digital resources for CLIL education in France. Therefore, she usually looks for resources websites about science education in English-speaking countries, notably American websites.

Laureen did not find the video ("Atoms, the clash of the titans"<sup>1</sup>) she had formerly used four years ago, either in her digital file or on the colleague's website. So she looks for "atom high school teaching" on search engine in order to find it. She adds words, such as "activity", to the series of previous words, so as to find it, but also to discover new resources. By doing this, she selects a resource entitled "build an atom". It is a matter of constructing atoms interactively and of finding the corresponding chemical element in the periodic table of Mendeleev. She considers it interesting in the sense that the students already have the scientific knowledge which, according to her, will not be favorable for the practice of the language. She is rather looking for English language activities or videos without having specific ideas of what she wants, only that the medium must allow oral interaction in the classroom and learning of a specific vocabulary. The scientific content must already be mastered by the pupils i.e. it must be tackled in common core before the CLIL teaching.

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<sup>1</sup> The video is available on the following website: <http://vfvilesieux.free.fr>

The teacher chooses to start her lesson with the video produced by the BBC and presented by Jim Al-Khalili, a Professor of Nuclear Physics. The extract lasts about five minutes. For the teacher, “this video is interesting because it tackles the history of science and the work of the scientist, because finally Rutherford’s experiment demonstrated that the model of the full atom, well a full sphere, didn’t work”. Thus, she chooses this video because it permits, i) to understand the scientist’s work in his laboratory, ii) to work in an epistemological perspective. She adds that “there is less oral work during the lesson, but at the same time there is a listening activity and they will practice oral English during the next lesson”. We see that the focus on oral practice is a priority, that is spread over the whole unit, even if this specific lesson also allows her to study the “definition of the atom and who present the different models”.

### ***Epistemic analysis of the resources***

The video chosen by Laureen deals with an experiment conducted in 1909 by Hans Geiger and Ernest Marsden under the direction of Ernest Rutherford, and carried out under vacuum. Radioactive material emitting  $\alpha$  particles (helium nucleus) is oriented towards a very thin gold leaf in front of a screen. This one is enriched with a chemical substance (zinc sulphide) allowing to visualize, by a luminous flicker, the collision by the  $\alpha$  particles. After a few minutes, different points of light appear on the screen and all of these points are not in the orientation of the beam.

This experiment shows that matter is a lacunar structure, that is to say that atoms are essentially constituted of “vacuum” and that the nucleus, which is positively charged, concentrates the whole mass of the atom. As a result of this experiment, Rutherford proposed a “planetary” model of the atom: the negatively charged electrons revolve around a positively charged small nucleus.

The beginning of the video, which is not shown to the students by the teacher, exposes the different studies carried out by other scientists to show the existence of atoms. The commentator explains that the existence of the atom is still debated in the scientific community and that Thomson’s model of “plum pudding”, proposed in 1904, was not shared by the community. He also points out that Rutherford made the discovery by studying the radiation  $\alpha$ , which is a form of radioactive decay, following Becquerel’s work on radioactivity. Students are not aware of this scientific context, and have never encountered such laboratory equipment. They have only heard about Thomson’s model which is studied in French.

As for the linguistic knowledge contained in the video, the man who speaks has a British accent. He speaks at an ordinary pace, and uses sentences with complex structures. He also uses several tenses (present, past, conditional), and many idiomatic expressions, such as “ran out of”, “a simple-enough task”. Furthermore, we can hear many occurrences of a specific scientific language (“alpha particles”, “sub-atomic world”,

“nucleus”, “electrons”...). A few proper nouns are heard several times (“Manchester University”, “Rutherford”, “Geiger”, “Marsden”), as well as large numbers (“one tenth of a millionth of a millimetre across”, “one in 8,000 alpha particles”...). These elements are likely to raise difficulties for the students.

We believe that this lack of context and problematization can make it difficult for students to understand Rutherford’s experiment. The results pile on others without any particular explanation, whereas a more advanced epistemological study could have helped the understanding. In addition, the experience is described in the video but not *shown*. Only the model of the Rutherford’s atom is presented with an animation. Moreover, students have never heard, in their chemistry classes, about radioactivity because it is not in the curriculum, nor about the properties of the various elements that are used to observe the flows of  $\alpha$  particles. We also note that the video does not have any subtitles.

A fill-in-the-gaps text, which is one-page-long, and which is the transcription of what is said by the commentator is handed out to the students before the video starts to be played. Here is a picture of what this text looks like:

#### FIGURE

Rutherford set his students a simple-enough task. Use the radium gun. Shoot the alpha-radioactivity at the gold leaf and with the phosphorescent plate, count the number of particles that come out the other side. In practice, that meant sitting alone in the dark and counting tiny, almost invisible flashes on the phosphorescent screen. It was deeply tedious (3), but Rutherford insisted that they keep at it. Weeks passed and the team of researchers found nothing .....[4]..... . The alpha particles seemed to punch through the gold almost as though it wasn't there. Very occasionally, they would swerve (4) .....[5]..... as they went through. Hardly front-page news! Now comes what must be the most consequential off-the-cuff (5) remark in the history of science, one that changed the world.

*Fill-in-the-gaps exercise*

We notice that the words in the gaps are not, at first sight, specific scientific words, in the traditional sense. These words are for instance “slightly”, “barely”, “thick”. Nevertheless, these words are essential in order to understand the experiment *fully and precisely*. The word “slightly” describes a specific trajectory of the atoms that bounce back when they encounter an obstacle (a phosphorescent screen).

In this fill-in-the-gaps exercise, speakers are not identified between the commentator and a voiceover. As a consequence, following the thread of the comment is challenging.

Moreover, the fact that this fill-in-the-gaps exercise is handed out, before the video is played, prevents the students from focusing on the video in itself.

The teacher stresses in the interview a possible origin of the difficulties encountered by the students to complete the fill-in-the-gaps text. Some have read it without watching the video and others have done the opposite. To remedy this, the teacher suggested

during an interview after the lesson that the video could have been played twice, and that the students would have had the text to complete only at the second passage.

We add the need to contextualize the study of Rutherford in the problematic following the work carried out by Thomson and Becquerel on the radioactivity. As in the video, the text contains several tenses, numerous idiomatic expressions, and many occurrences of scientific words and expressions that are specific to Rutherford’s experiment. Besides, the style is very formal. We hypothesize that this high epistemic density and, thus, complexity, of these resources is likely to generate comprehension difficulties for the students.

## ANALYSIS OF THE TEACHER’S PRACTICE

### Episode 1

The first episode occurs after watching, only once, the video while Laureen introduces a vocabulary activity by asking students to explain the results of Rutherford’s experiment. She first reminds them that before Rutherford, Thomson had proposed a model that was not unanimous. Then, she makes her students work on the fill-in-the-gaps text.

TABLE 1

Episode “Gold leaf”		
17	Teacher	So what did you find in number 1? Who wants to answer? Number 1? Did you get it? Because it was... You didn’t? What could it be? If you read the sentence, what could it be? Do you know what is a gold leaf?
18	Student	No
19	Teacher	What is a leaf?
20	Student	Feuille
21	Teacher	Yeah, a leaf, what is a gold leaf?
22	Student	Une feuille d’or
23	Teacher	Yeah, a leaf made out of gold, something very very... thin. OK so it could be a few atoms what? What is the property of this leaf ( <i>shows a sheet of paper</i> )? If you look at its property, it’s very thin so we can talk about the thickness. What is the thickness of this leaf? How thick is it? Well it could be just a few atoms thick. It has the thickness of a few atoms. That was the property of the gold leaf that he used. Thick, so it has the thickness of just a few atoms, it was very very thin
24	Student	<b>Just a few atoms thick?</b>
25	Teacher	Thick! That’s its size! You stop me if there is a problem. So number 2, a movable phosphorescent screen that flashed when... you didn’t get this one probably... struck! ( <i>writes “struck” on the board</i> ) It means that when you have alpha particles that are hitting the gold leaf the phosphorescent screen flashes. Samey number 3?
26	Student	<b>Euh</b>
27	Teacher	<b>You didn’t hear it?</b>
28	Student	<b>No</b>

We can see that, from the first speech turn (ST17) of the fill-in-the-gaps activity, the students do not find the answers. Laureen asks them (ST23) to guess the missing word (“thick”) from the meaning of the following sentence: “Gold leaf, beaten till it’s just a few atoms...”. She asks the meaning of “gold leaf” and then gives the missing word: “thick”.

Concerning the second sentence of the exercise, “a moveable phosphorescent screen that flashed when... by radioactive waves”, she gives directly the answer: “struck” (ST25). The gap in this sentence is quite difficult to identify, for two reasons. Firstly, the word “when”, followed by a past participle, is a specific structure of the English language, that cannot be translated word for word in French. Secondly, the concept of radioactive wave has not been studied yet by the students. What is more, the word “struck” is specific to radioactive phenomena. It describes how an emission of waves, moving at a certain speed, encounters an obstacle, the phosphorescent screen, and strike it. The words, “touched”, or “knocked”, or “bumped”, for instance, could not have been used. The description of radioactivity is associated with its proper discourse, its own “practice language” (Collins, 2011), that Wittgenstein (1997) called the “language game”. That is to say a language that is necessary, within the practice of describing radioactive phenomena, in order to tell precisely what occurs to atoms, and to be understood about is told. What is specific in CLIL science classes is that students have to practice the language game of science knowledge, as it is usually done in ordinary teaching, but, in this context, *a language game in a foreign language*.

In addition, the role of the equipment that is necessary to the success of the experiment, such as the gold leaf and the phosphorescent screen, is not explained in the video. Besides, the laboratory equipment that is needed for the experiment is very specific and is never used at school.

The teacher questions the students at the end of the video about the results of the experiment and not about the experimental protocol that has produced these results. However, we shall see that the first questions of the document to be completed require a clear understanding of the experiment. Moreover, the video has only been played once.

So, we notice that Laureen either gives the answer or explains the meaning of the word in the context of the experiment, or comes back to its context so as to help the students guess the words. She also gives some answers that the students do not find. She sometimes translates the words into French. All these strategies enable her to make chronogenesis go faster. Indeed, the students had initially to complete the sentences while listening to the video. By providing the answers, the teacher is in a high topogenetic position. We could say that, in order to continue a form of communication, based on a “question and answer” learning game, the work on the milieu leaves room for a certain continuity based on a “communication contract” (Gruson, 2006; Kewara, 2012). We observe an alteration of the learning game in the sense that the communication

logic takes over the epistemic logic<sup>2</sup> (Sensevy, 2011). The scientific epistemic density is weakened and the contract-milieu relationship is unbalanced. Indeed, the use of the fill-in-the gaps resource, that is to say, the work at the sentence level, does not allow the teacher to ensure that all students have understood the experience and the results, and therefore to work (relatively) authentically on comprehension. We could add, following a study on oral comprehension (Roussel, Gruson & Galan, 2017), that the focus on low-level cognitive processes that are weakly automated in learners does not mobilize high-level processes and build overall meaning. Thus, language proficiency, if poorly mastered, prevents access to content.

### Episode 2

In the following extract, the teacher is working on a gap in the text. The missing word in the sentence is “back” (“The alpha particles seemed to punch through the gold almost as though it wasn’t there. Very occasionally, they would swerve... as they went through”). The episode occurs while the students do not succeed in finding the word “back”.

**TABLE 2**

<i>Episode “Swerve back”</i>		
<b>40</b>	<b>Teacher</b>	They swerve, if you look at the definition of swerve: to change directions suddenly. So what direction could they take?
<b>41</b>	<b>Student</b>	Of the atom
<b>42</b>	<b>Teacher</b>	Hum... Yeah... Euh...
<b>43</b>	<b>Student</b>	Right or left?
<b>44</b>	<b>Teacher</b>	Yeah, but is there something that would make them go right or left?
<b>45</b>	<b>Student</b>	Directions
<b>46</b>	<b>Teacher</b>	Mmmm... So we have the verb, the verb is swerve so they can change their direction we have the verb we want to know in which direction
<b>47</b>	<b>Student</b>	When as they went through
<b>48</b>	<b>Teacher</b>	No, not when because we have an “as” afterwards. They swerve back, they change direction and instead of going through it ( <i>mime of back and forth with the hand</i> ), they swerve back ( <i>writes “back” on the board</i> ).

Here, we observe Lauren doing a grammatical activity so as to help her students produce the correct answer. We observe that her strategy distracts the students from the scientific content of the experiment. Here again, the focus on low-level processes

2 According to Sensevy (2011), the logic is a “system of necessities” that structure the background of a practice.

of comprehension does not give access to the global sense of the message (Roussel, Gruson & Galan, 2017).

On the other hand, we assume that if the students do not know how to answer, it is due to the fact that they have not understood the experiment, and notably that a flood of particles strikes gold atoms and is deflected in the opposite direction. The teacher does not recontextualise the answer (ST48) by stating one of the results of the experiment but remains on the language. The language learning is mostly lexical. We can also add, concerning the answers produced, that the teacher may be “sometimes unable to determine whether it is the lack of knowledge or language skills that prevents students from demonstrating their knowledge” (Gablasova, 2014, p. 152). Besides, the fact that Laureen moves from an activity focused on the comprehension of the experiment to a grammatical explanation (ST46) can be described as a shift in the game. She shifts from the “question and answer” learning game to a grammatical game, made necessary by the students’ impossibility to answer because of their lack of language skills related to the verb particle “back”.

In this episode, the communication logic does not take over the epistemic logic. Indeed, Laureen slows the chronogenesis down in order to provide a grammatical explanation: the epistemic logic takes over the communication logic. But, when she provides the answer (ST48, “they swerve back”), the communication logic takes over the epistemic logic because it is necessary for her to keep on answering the questions. By doing that, she makes the chronogenesis go faster. What is more, we have noticed that she is mistaken in the answer that she provides. The expected word should be “slightly” and not “back”. Indeed, from a scientific point of view, a tiny fraction of the alpha particles are deflected by more than  $90^\circ$  (“slightly”) and do not go exactly “backwards” (“back”). This meaning is important in the understanding of the experiment, and is related, as in the first episode, to the English language game necessary to describe precisely what occurs to atoms. This is all the more important as the word “slightly” is not usually seen as a word of the scientific jargon relative to atoms. But, in this precise situation, it does constitute a jargon, in the sense of a specialised language, relative to a situation.

### **Episode 3**

The following episode, extracted from the transcription of same lesson, occurs while the teacher is drawing, on the blackboard, a sketch from Rutherford’s experiment, as it has been presented in the video.

The teacher’s sketch represents alpha rays going through a line that symbolizes the nucleus of an atom. She asks a student, Max, to describe what happens to the alpha rays (ST142). He answers that the rays “pass out” (ST143). The teacher approves his answer, and adds “they go” (ST144). Max (ST145) answers “straight”, followed by the teacher who repeats “straight”, but adds “through” (ST146). Max repeats “straight

through” (ST146). His pronunciation is mistaken. The teacher asks him to “make an effort” (ST147); he eventually pronounces correctly the expression (ST149).

**TABLE 3**

<i>Episode “Straight through”</i>		
<b>I42</b>	<b>Teacher</b>	<b>Max, what happens to those alpha rays?</b>
<b>I43</b>	<b>Max</b>	Quite all the alpha rays pass out...through ( <i>mispronounced</i> )
<b>I44</b>	<b>Teacher</b>	Yeah, they go ( <i>shows the word “straight” on the board</i> )
<b>I45</b>	<b>Max</b>	<b>Straight</b>
<b>I46</b>	<b>Teacher</b>	<b>Straight through</b>
<b>I47</b>	<b>Max</b>	Euh, straight through ( <i>mispronounced</i> )
<b>I48</b>	<b>Teacher</b>	<b>Oh make an effort!</b>
<b>I49</b>	<b>Max</b>	<b>Straight through</b>
<b>I50</b>	<b>Teacher</b>	<b>Yeah</b>

The expression “straight through” has already been heard in the video. It is also mentioned in the fill-in-the-gaps exercise. It is notably a gap to be filled in the text. So, when the teacher insists upon “straight through”, it is actually the third occurrence, within the lesson, of this expression, as knowledge to be learnt.

The teacher’s insistence upon the use, and the pronunciation, of “straight through” shows that she uses several resources so as to shape them strategically. These resources are considered as relevant resources according to the type of activity that she sees as necessary for CLIL lessons, that is to say the practice of oral English. To play the expected “learning game”, the student has to use the following strategy: answering accurately and pronouncing adequately enough according to the teacher’s expectations within the context of a CLIL lesson. The organisation of the video, with the fill-in-the-gaps text, and with the sketch, is oriented towards the development of oral skills in English. Speaking as much as possible in English is part of the didactic contract of CLIL lessons.

Max’s answer seems to be right: he tries to explain that almost all the alpha rays go straight through the gold, but hesitates between “pass out” and “pass through”. From a linguistic point of view, his answer is not valid because the word “pass” is not an equivalent of “go” in English. He actually refers to the French verb “passer” and transfers it to the English language to explain what happens to the alpha rays. Furthermore, the fact that the teacher is French allows her to understand Max’s proposition and to validate it. With respect to Max’s use of English words, Laureen actually displays enough flexibility to allow him to provide an answer. Le Hénaff (2013) has called this habit the “contract of tolerance for the ambiguity” in the discourse, to describe habits of communication that go beyond ambiguous details that are not fully understood, in order to maintain the communication flow.

This extract is emblematic of what is at stake during CLIL lessons: the teachers have to search for a balance between a focus on specific scientific knowledge and on the language practice. They are pulled between the contract (habits of communication, willingness to make the students speak) and the milieu-problem that has to be worked on (the scientific knowledge in another language).

In this situation, we could say that Laureen arranges the didactic milieu (the knowledge to be learnt), constituted of both linguistic and scientific contents, as a milieu that is very oriented towards oral linguistic knowledge. Indeed, she insists upon the pronunciation of “straight through” whereas Max’s answer is scientifically valid. The fact that she validates “pass out” (ST143) is also a sign of her willingness to make the students speak.

## DISCUSSION

### ***Choice and use of resources and didactic contract***

In this case study, we have observed that the habits of communication and, more particularly, the didactic contract of communication in oral English, strongly determine the teacher’s relationship to her documentational work. However, there are other elements involved in the didactic contract of the class. The teacher told us, during an interview, that she had chosen a topic related to the students’ personal interests, and which is not necessarily linked to the common core curriculum in physics and chemistry. For the teacher, it is a matter of encouraging students to speak and enabling them to learn new scientific knowledge, whether or not they complement those acquired in the core curriculum. This result echoes a recent study on English teacher’s resources that has shown that stimulating students’ engagement to speak influences English teachers’ documentation work (Gruson, Gueudet, Le Hénaff & Lebaud, in press). For all that, we observe her insisting on the pronunciation of words without focusing on grammatical or lexical mistakes. The promoting of oral expression is an essential aspect of the teacher’s habits of CLIL teaching. As a consequence, the exploration of the didactic milieu is mainly oriented towards the practice of oral English.

Therefore, the selection of the Rutherford experiment video is consistent with the didactic contract described above. The work on vocabulary is done via a fill-in-the-gaps text. It is in preparation for a second work on unstable chemical elements (radioactive). However, the resources selected by the teacher, notably the video, contain many occurrences of idiomatic and specific linguistic knowledge, which is too remote from what the students already know. The resources also contain scientific knowledge that is very specific to the scientific “practice language” relative to atoms. For instance, the understanding of the experiment, through the description of the radioactive phenomenon with the waves that *strike* the screen and that *swerve slightly*

is closely linked to the understanding of these words within a specific experiment, here Rutherford’s experiment. When the distance between the didactic contract and the milieu seems too important, the teacher has to adjust the epistemic density of scientific and linguistic knowledge to each other. All the delicacy of the teacher’s work consists in trying to alter as little or as abruptly as possible the epistemic density of one content relatively to the other.

### ***CLIL teaching: a twofold complexity***

In order to make students experience both science and the foreign “language practice” of science, CLIL teachers have to make their students deal with linguistic and scientific knowledge. This knowledge should not contain too much epistemic density (Marlot, 2008; Sensevy, 2011), but rather some specificity that still permits to mobilise adequately previous knowledge. Consequently, the teaching of a scientific subject in a foreign language requires an ongoing search for a balance between epistemic density and specificity of the linguistic and scientific contents. The shifts in the games, such as the move we observed from a comprehension activity to a grammatical explanation, could be typical for CLIL lessons, and for this ongoing search, by the teachers, for a balance between the linguistic and scientific knowledge at stake in order to avoid that the communication logic takes over the epistemic logic.

We have previously shown that communication logic and epistemic logic are related to chronogenesis. For example, if the teacher gives the answer to the question asked or translates a word or sentence into French to help students, the communication logic takes over the epistemic logic and the chronogenesis is accelerated. The teacher has a high topogenetic position which allows her to act on the mesogenesis and on the chronogenesis, sometimes to the detriment of knowledge construction. The translation is particularly characteristic of this grip on the didactic actions by the teacher.

However, this allows her to be reassured about the expected duration of the lesson. In the opposite case, as when the teacher produces a grammatical explanation, the epistemic logic takes over the logic of communication and the slowed down chronogenesis. The teacher acts on the chronogenesis, which seems to favour the learning but makes her insecure about the expected course progress. The topogenetic position of the teacher is in this case rather low.

Thus, teaching and learning science in English constitutes a twofold complexity, because of the focus on two objects of learning. As Gablasova (2014) put it, it can be highly complex for teachers to identify in action, between science objects and language objects, the causes of students’ potential difficulties.

We have chosen to focus on a case study, while bearing in mind that the question of the replicability of this type of study, which is highly context-dependent, must be questioned. In fact, our study makes it possible to build avenues for discussion and

reflection on CLIL programmes, which could feed other studies on this point. The idea of analysis from the case study is to allow a better description and understanding of phenomena, for example here, in order to highlight the complexity, within actual practices, of the advancement of knowledge.

## CONCLUSION

Our analysis has shown that, in the episodes, the scientific and linguistic knowledge both advance, but in an asynchrone move. The teacher cannot focus the students' attention on both types of knowledge with the same epistemic density. Thus, while a particular type of knowledge is addressed, the other one remains in the background, but is not eluded.

Language and content advance in parallel but rarely meet an intersection point. This should therefore be the characteristic of the "integrated" component in CLIL programmes.

Besides, the habit of making students practice oral English (the didactic contract) orients the teacher's selection and use of resources. She says, during her preparation work, that she wants to make her students learn scientific vocabulary in English, in the classic sense of "scientific vocabulary", that is to say names of concepts or phenomena. But, as we have seen, studying words within their context, inside their proper language game, is essential for the understanding of scientific phenomena. The word "slightly", for instance, makes it easier to understand exactly the sinuous path of the atoms that are bouncing back.

In CLIL lessons, this study is all the more complicated as it is in a foreign language and, consequently, it is all the more important not to elude this work. Understanding a practice language (Collins, 2011) helps understanding a scientific practice. That is, moreover, why scientific and linguistic knowledge are so closely linked and necessarily both advance in CLIL lessons, even if it is not at the same pace, but in an asynchrone move.

It seems necessary to develop, in CLIL lessons, the study of language items that allow to better understand scientific actions, results and descriptions, in order to make both advance scientific and linguistic contents. As an example working with resources in English, but also in the students' first language, could also be an original way to address this issue.

Following these initial findings, it seems crucial to underline that teachers of "non linguistic subjects" are not language teachers and therefore require specific training (Duverger, 2007). For instance, non linguistic teachers are not familiar with that fact that, in foreign language classes, language teachers usually play videos three times in class, so as to ensure that students understand them as much as possible.

But, as Mehisto (2008, p. 108) stated, "CLIL teachers are often not trained or certified to teach in CLIL". Conversely, the place of non language teachers, who could conduct chemistry lessons, should also be questioned. Mehisto (2008, p. 113) insisted on the fact

that “many teachers find it difficult to apply a multiple focus on content and language, as well as on cross-curricular integration”: thus, allowing science and language teachers to work together should be a way to support them in their reflection, for instance, on epistemic and communication stakes in their lessons, with respect to what we observed about the relationship between the epistemic logic and the communication logic. Moreover, Fortune, Tedick and Walker (2008, p. 85) pointed that “teachers need to understand their roles as both content and language teachers”.

And, as Collins (2011) put it, “domains of practice/language are embedded within one another in fractal-like relationship”, and the teacher of our study tries to adopt what could be called, in reference to the Common European Framework of References for Languages (Council of Europe, 2001), an “action-oriented” approach. She chooses and organizes resources that are mostly oriented towards the practice of English, in order to make the students act with the foreign language. Thus, joint preparation or joint teaching could have helped her to make her students better explore the problem at stake, such as the understanding of the video.

Moreover, co-teaching, but also the selection and conception of resources by collectives of science and language teachers, is a path that could be explored. This way of working is much more developed in some Asian countries (Miyakawa & Winslow, 2009), and is tending to spread in western countries, but these “lesson studies” are still to be developed. That kind of group work is not strictly focused on resources but takes into account the way they are integrated into the existing resources systems, and into didactic situations that generate collective reflections, implying diverse participants. It can result in what Gueudet and Trouche (2008b) call “common documentations”, notably thanks to the study, by the participants, of the “instructions for use” of the textbooks and their teaching guides (Miyakawa & Winslow, 2009). This would be all the more important as the number of resources that are currently available is quite reduced. Besides, Mehisto (2008, p. 110) argued that CLIL teachers, in order to create opportunities for reflection about their practice, could conduct “self- and guided-analysis of teacher-chosen sections from their own filmed lessons”. Participants to lesson studies frequently conduct such analyses.

For the training of teachers, it is therefore important to understand that the ability to select and analyze didactic relevance of a resource is crucial for their future teaching. Currently, which tools do they have at their disposal to analyse the didactic relevance of a resource? The epistemic analysis we produced enabled us to identify the knowledge at stake and anticipate the difficulties that the use of the selected resources could produce. Such a tool would benefit from being further highlighted in the training of teachers, although we are aware that it is not possible for them to spend all their preparation time analysing the resources they pre-select for their coming lessons.

Furthermore, teacher training should be more focused on the development of

collective epistemic studies of resources that are selected. As Gruson and Marlot (2016) put it, “teachers must be adequately trained to seriously investigate the knowledge involved, mainly before implementing the situation”. Adler (2015, as cited in Gruson & Marlot, 2016, p. 12) also insisted on the importance “to create time for teachers out of school where they themselves have opportunity to participate in various practices, practices that deepen their .... knowledge for and in teaching ...., providing opportunity for teachers to appreciate that their knowledge-in-use is a key resource in their practice”.

Eventually, as many studies have been carried out in the field of CLIL, emphasis should be placed on the importance of the variety of programmes and therefore of the types of knowledge involved, and expected by teachers. As Dalton-Puffer (2011) pointed, CLIL programs are characterized by a huge variety and by differences between national educational cultures.

The questions we ask, and the possible answers to them, are therefore made in the light of these specificities. The question of which disciplinary and language content fits into each other is therefore also to be studied according to the great diversity of these programmes, in France but also in Europe.

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