The scientific laboratory as a learning setting in CLIL

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Résumé : L'approche CLIL se propose de mettre les apprenants au centre du processus d'apprentissage d'une discipline non linguistique, et de favoriser le développement des compétences cognitives et communicatives à travers l'utilisation d'une seconde langue. Le laboratoire scientifique regroupe tous les éléments-clés du CLIL, et peut être réalisé en trois phases. La phase initiale est caractérisée par des activités de remue-méninges pour activer les connaissances précédentes sur la discipline, l'identification de mots-clés et de structures lexicales, la recherche et l'adaptation de matériels à partir de textes et de la Toile, l'identification de un ou plusieurs problèmes représentant l'activité expérimentale, les hypothèses sur les résultats. La phase centrale comprend la conception et la réalisation de l'activité expérimentale, la collecte des données ainsi que leur élaboration et leur présentation, le jugement collectif pendant l'activité, et la rédaction du compte-rendu de laboratoire. La phase finale consiste en une séance plénière de commentaire des résultats et des conclusions, en comparaison entre les hypothèses et le résultats, en évaluation des procédures expérimentales, en jugement individuel sur le compte-rendu de laboratoire, et en évaluation finale. Le laboratoire présente de nombreux aspects positifs: il peut être conduit selon différents niveaux de compétence linguistique et à n'importe quel moment de l'année scolaire, il permet le développement des compétences linguistiques et cognitives, il se base sur les approches *problem solving* et *inquiry-based*. Enfin, il représente une opportunité pour développer des capacités de socialisation s'il est effectué par petits groupes.

Mots-clés : laboratoire scientifique, activités expérimentales, compte-rendu de laboratoire.

Riassunto: L'approccio CLIL si prefigge di porre gli studenti al centro del processo di apprendimento di una materia non linguistica e di favorire lo sviluppo delle competenze cognitive e comunicative attraverso l'uso di una seconda lingua. Il laboratorio scientifico racchiude tutti gli elementi chiave del CLIL e può essere realizzato in tre fasi: fase iniziale, centrale e finale. La fase iniziale è caratterizzata da attività di brainstorming per attivare la conoscenza pregressa sulla materia, l'identificazione di parole chiave e strutture lessicali, la ricerca e l'adattamento di materiali da testi e dalla rete, l'identificazione di uno o più quesiti rappresentanti l'attività sperimentale, ipotesi sui risultati. La fase centrale comprende la progettazione, realizzazione dell'attività sperimentale, raccolta, elaborazione e presentazione dei dati, giudizio collettivo durante l'attività, stesura di resoconto di laboratorio. La fase finale consiste nella discussione plenaria dei risultati e le conclusioni, la comparazione tra le ipotesi e i risultati, valutazione delle procedure sperimentali, il giudizio individuale sul resoconto di laboratorio, valutazione sommativa. L'approccio laboratoriale presenta molti aspetti positivi: può essere svolto in diversi livelli di competenza linguistica e in qualunque momento dell'anno scolastico, consente lo sviluppo delle competenze linguistiche e cognitive, si basa sugli approcci *problem solving* e *inquiry-based*. Infine rappresenta un'opportunità per sviluppare capacità sociali se rappresentate in piccoli gruppi.

Parole chiave: laboratorio scientifico, attività sperimentali, resoconto di laboratorio.

Abstract: CLIL approach aims at placing students at the centre of their learning process of a non-linguistic subject, developing cognitive and communication skills through the use of a second language. Scientific laboratory includes all the key elements in CLIL and can be performed in three phases:
-Initial phase → brainstorming in order to activate students' prior knowledge on the topic; identification of keywords and lessical structures; search and adaptation of materials from texts and web; identification of one or more questions representing the aim of the experimental activity; prediction of the results
-Central phase → design and performance of the experimental activity, collection, processing and presentation of data; group assessment during the activity; filing a lab report
-Final phase → plenary discussion on results and conclusions; comparison between predictions and results; evaluation of experimental procedures; individual assessment on the laboratory report; summative assessment.
Laboratory approach present many positive aspects:
- It can be performed at different school levels and anytime during the school year
- It allows the development of language and cognitive skills
- It is based on *problem solving* and *inquiry-based* approach
- It represents the opportunity to develop social skills if performed in small groups.

Keywords: scientific laboratory – cell – experimental activity – laboratory report.

Introduction

CLIL approach aims at placing students at the centre of their learning process of a non-linguistic subject, developing cognitive and communication skills through the use of a second language (L2). CLIL approach is defined as a « dual-focused education in which an additional language is used for the learning and teaching of both content and language » (Coyle, Hood, Marsh: 2010).

Similarly, Bentley defines CLIL as an « approach or method which integrates the teaching of a content from the curriculum with the teaching of a non-native language ». The main goal is to move learners from BICS (Basic Interpersonal Communicative Skills) to CALP (Cognitive Academic Language Proficiency), since « language used in subject teaching is often abstract and formal and therefore is cognitively demanding » (Bentley, 2010).

During the years, the term CLIL has been referred to as a method, a methodology and an educational approach and the key elements have been identified as:

- *Content* → curricular subject and topic taught in the CLIL module
- *Communication* → development of oral and written language skills to encourage student participation in class and increase student talking time
- *Cognition* → development of thinking skills such as hypothesising, reasoning, evaluating, synthesising.
- *Culture* → cultural context of the student, favouring the knowledge and understanding of other countries and cultures as well as awareness of the environment.

Practical examples of CLIL approach in primary and secondary school are provided by Mehisto et al. (Mehisto, Marsh, Frigols, 2008). In the text, the Authors emphasize the importance of an appropriate setting of the learning process through linking outcomes to content, language and learning skills. The language is not the primary subject being taught therefore the quality of content should not be compromised by the lack of language knowledge. In terms of language skills, the Authors suggest to create a wide range of opportunities to use all the language skills, encourage language growth by creating a psychologically-safe learning environment and remember that communication is of primary importance in the CLIL approach.

The use of the scientific laboratory involves all the above aspects of CLIL and represents a powerful way to encourage an enquiry approach, since it can be associated to other methodological approaches such as *problem solving* or *problem-based learning* (PBL), *task-based learning* (TBL) and *inquiry-based scientific education* (IBSE). When performing an experiment, students should develop several cognitive skills necessary to plan and design the experiments, select the appropriate variables and tools, observe and take measurements, collect and process data, describe results, draw conclusions and evaluate the experimental procedure as well as the reliability of the results. Moreover, the scientific laboratory allows the development of language skills such as reading, listening, speaking and writing and places the student at the centre of the learning process in a funny and meaningful way (*active learning*); it also represents a good opportunity to develop social skills through cooperation with classmates, in pairs or in small groups (*cooperative learning*).

The scientific laboratory represents a very flexible learning context in terms of physical place where the activities are performed, age of the students and time of the school year in which the CLIL module is conducted. Teachers can perform scientific activities in the school lab, if available, as well as simple experiments in class or in the computer lab, since many laboratory softwares are now available. Moreover, the adequate choice of topics and experiments allows the performance of lab activities with students from primary to secondary school.

Teacher's work is very important in every step of the activity: at the beginning, during the activity itself and at the end of it. In the initial steps, the teacher must look for material to use in class carefully, modifying and adapting it to the class in terms of content and language. The use of glossary, visual organizers, diagrams and animations could be examples of scaffolding related to content; reducing of the length and/or paraphrase of sentences and highlighting keywords and vocabulary can be useful in the language adaptation.

One of the most important steps at the beginning of the activity is to encourage student motivation; in this sense, it could be useful to start with one or more questions, so that students could answer them through the experimental activity. Brainstorming activity posing open questions at the beginning of the lesson can be very powerful to activate students' prior knowledge, encourage learners to share ideas with the other students and stimulate their curiosity. Students should design and perform the experiments in an autonomous way, according to their age and the type of instrument required; only in few cases, a teacher should show the activity or anticipate the answers to the research questions.

A high motivation will also be achieved when students are challenged with progressively cognitively demanding tasks that can stimulate high-order thinking skills and cooperation with classmates. The book by Deller and Price (Deller, Price, 2007) is a very useful tool to help teachers in planning and performing meaningful classroom activities; it also provide examples of language to help teachers preparing the lesson, giving out material, asking questions, giving instructions, encouraging and redirecting, ending the lesson, and examples of language to help students asking for and giving opinions, classifying and contrasting, describing a process of cause-effect, evaluating, defining and describing, sequencing…

Lab work in pairs or in small groups adopting a *cooperative learning* strategy allows an easier management of the class and the development of social skills. The following lab activities can be used in CLIL modules teaching Science in English. These activities, with due modifications, can be used from primary to secondary school levels.

1. Planning the experimental activity

Before starting with the experimental activities, the teacher should identify:

1.1 Global goal

The following experimental activities on the cells can be performed during a CLIL module on the cells in order to deepen the knowledge of the structure and function of the cells and to become more familiar with experimental activity in the lab.

1.2 Teaching aims

Encouraging students to ask questions and address them through experimental activity; developing the ability of planning an experimental activity in an autonomous way; encouraging student talking time; stimulating active learning; developing social skills through groupwork and cooperative learning.

1.3 Prerequisites

Biological molecules, cell theory, microscopes, size of cells, prokaryotic and eukaryotic cells, structure of animal and plant cells, types of transport across cell membrane.

1.4 Cognitive skills

In order to identify cognitive skills, the teacher can refer to Bloom's taxonomy modified by Anderson and Krathwohl described in Coyle (Coyle, Hood, Marsh, 2010). Cognitive skills are the processes used by the brain when we think and learn. Here, some of them are listed: remembering, identifying, ordering, rank ordering, defining, comparing and contrasting, dividing, classifying, predicting, hypothesising, reasoning, synthesising, evaluating. Questions and tasks should be appropriately planned in order to develop each of these cognitive skills.

1.5 Learning outcomes

At the end of the activity, the student should:

- *know* the name of the lab equipment and tools, how the light microscope works and how to observe cellular processes such as osmosis and phagocytosis.

- *be able to* plan a scientific investigation, record and process data, present data using visual organizers, draw appropriate conclusions, work in groups and file a laboratory report.
- *be aware of* the importance of the microscopy in biological and medical science, as well as of the way researchers work in the lab and how they file a laboratory report.

1.6 Time

The time for each activity is indicated in parenthesis. The time should be defined by the teacher at the beginning of the CLIL module and should include the time for the lesson in class and that for the experimental activity.

2. Experimental activities on cells

The teacher can plan a qualitative or a quantitative experimental activity, depending on the teaching aims. A qualitative experiment can be performed by observing an event or an object with nude eyes or with an instrument such as the microscope and the output will be a description of a phenomenon in words or with a drawing; a quantitative experiment, on the other hand, requires measuring, recording and processing data and presenting them using appropriate visual organizers, interpreting the results and drawing conclusions.

In order to avoid accidents in the lab, it is mandatory to provide students with lab safety indications, clearly explaining the safety rules and the meaning of safety symbols of the chemicals and be sure about their understanding of risks related to the use of reagents and instruments[1].

Below, examples of both types of activities are described. At the end of each activity, examples of assessment are also provided.

2.1 Activity 1. Qualitative investigation. How do the cells look like?

2.1.1 Brainstorming in class (1 hour)

Aims: activating prior knowledge, developing cognitive skills and communication skills.
Cognitive skills (LOTS) and tasks: defining and remembering (« Define the principles of cell theory »; define « cell », « prokaryotic », « eukaryotic », « unicellular », « multicellular »; recall the size of different types of cells); identifying and naming (« Identify the main features of living organisms, name an example of unicellular and multicellular organism »; « Name the cytoplasmic organelles of the cells »); rank ordering (« Order the cells/organisms according to the size »); classifying (« Classify living and non-living objects using a T chart »); comparing and contrasting (« Compare and contrast animal and plant cells using Venn diagram »).
Cognitive skills (HOTS) and tasks: predicting (« What happens to a plant or an animal cell when we put into it a hypotonic or a hypertonic solution? »; « Which specimen will be stained by Lugol, a dye specific for starch molecules? »); hypothesising (« Why were the first living organisms unicellular and photosynthetic? »; « How might the different functions of the cells affect their shape and structure? »; « Suggest the role of the cell wall in plant cells and prokaryotes »); reasoning (« Explain why cell specialisation has been important during evolution »; « Explain why Lugol stains starch granules »); Creative thinking, synthesis (« Plan a simple experiment aiming to identify starch-containing food »); evaluating (« Which is the most appropriate instrument to use? »).

The teacher should not comment on the predictions, since they represent the research questions.

Communication skills and tasks: grammar and lexical structures (identify keywords and find their meaning – glossary; identify lexical structures – verb tenses, active and passive form of the verbs, comparatives and superlatives); speaking (discussion in pairs, then with whole class; increasing student talking time; stimulating the use of L2 in an informal way and in a content-related environment); listening and writing (listen to a video, then complete the text choosing the appropriate words, answer the questions and write a short summary).

2.1.2 Brainstorming in lab. (10 min)

Task 1: « Which instrument do we need in order to observe the cells? ». The teacher should provide pictures of different instruments - magnifying lens, microscope, telescope, eyeglasses, binoculars - asking students to indicate which is the most suitable instrument. The students should use their knowledge about the size of the cells.
Task 2: « Which lab tool do we need? ». The teacher should provide pictures of different tools or show the real object in the lab. The aim is to learn some content-specific vocabulary.

2.1.3 Experimental procedures (1 hour)

Task 1: prepare the cells from a red onion epidermis layer, stain with methylene blue dye, observe at the microscope; draw what you observe.
Task 2: prepare cells from plant leaves and observe them in the microscope, draw what you observe.
Task 3: prepare the cells from mammalian liver, stain with methylene blue dye, observe in the microscope, draw what you observe.
Task 4: prepare the cells from potato and banana pulp, stain with Lugol dye, observe in the microscope, draw what you observe.
Task 5: identify bacteria using methylene blue staining
Task 6: observe the process of phagocytosis performed by paramecium eating red-stained yeasts
Task 7: compare osmosis in plant and animal cells

2.1.4 Plenary discussion in class (1 hour)

Aims: discussing results and conclusions; developing cognitive skills and communication skills.
Cognitive skills (LOTS) and tasks: defining (« What are the green structures that are present in the plant cell from the leaves? »; « What are the black granules observed in the potato and banana pulp? »); identifying (« Which type of bacteria are in sample A and B? »); defining (« What is osmosis? »); classifying (« Classify unicellular and multicellular organisms using a T chart »); comparing and contrasting (« What do plant cell and animal tissues have in common? »; « What are the differences and similarities between yeasts and bacteria? »).
Cognitive skills (HOTS) and tasks: predicting (« In which other type of food do you expect to find starch granules? »); hypothesising (« In your opinion, why don't you see cytoplasmic organelles such as ribosomes or mitochondria? »; « Which application can you envisage for the microscope in the medical field? »); reasoning (« Why animal and plant cells behave differently when they are put in hypertonic solution or in hypotonic

solution? »); creative thinking (« Plan a simple experiment aiming at identifying starch-containing food »); evaluating (« Evaluate the experimental procedure »; « Provide reasonable suggestions for improvements »).

2.1.5 Task-based activity (1 hour)

In small groups, design a simple experiment aiming at identifying starch-containing food
Aim: stimulate students to design and perform a scientific experiment in an autonomous way.
Cognitive skills: hypothesising, reasoning, creative thinking, evaluating
Communication skills: writing and speaking
Learning skills: planning and carrying out investigations, cooperating with others, locating and interpreting information, observing using senses, processing knowledge, recording results, summarizing, solving problems, using knowledge.
Instruction to students: select at least 10 different types of food; perform the experiment in lab (or in class); collect your data in a suitable table; summarize your results and draw conclusions; discuss your results within the group; evaluate your procedure and conclusions; discuss your conclusions with the whole class.

2.1.6 Assessment: summative test (1 hour)

The summative test must be administered at the end of the CLIL module. « Its purpose is to review learning of subject content and to help us know what learners have achieved at a specific time » (Bentley, 2010).
Such test can be oral or written and should include various typologies of questions to assess the different levels of achievement of each student. For each learning outcome, the teacher should carefully define the assessment criteria that can be expressed as *Can do* statements. The results can be expressed in marks.
The test is in English therefore it is important to ensure that the level of language knowledge doesn't interfere with the assessment of the content knowledge and viceversa. This key issue has been clearly analysed by Coyle and colleagues (Coyle, Hood, Marsh, 2010).
Administering multiple choice questions or asking students to label pictures and to complete a concept map choosing words from a list or a cloze (text with gaps) could be possible ways to assess the content mainly, since the teacher provides the words / language needed; if the knowledge of content-specific vocabulary is the focus of the assessment, then the teacher should ask open questions. Finally, asking to complete a concept map without providing a list of words, design a binary key or describe, explain and summarize what happened during an experiment represents a further level of assessment in which both content and language are definitely more integrated.

2.2 Activity 2. Quantitative investigation. Which is the effect of sugar concentration on osmosis in potato?

2.2.1 Brainstorming in lab. (10 min)

Task 1: predicting. « What happens if a piece of potato is put into a concentrated sugar solution or in distilled water? ». The teacher asks the students to make a prediction on the basis of what they know about osmosis in plant cell.

Task 2: experiment planning. « How can we plan a fair test? ». The teacher explains concepts such as « fair test », « dependent and independent variables », « control factors » which are very useful when planning and performing an experiment. Students should then identify the variables and the control factors in the experiment.

2.2.2 Experimental procedure

Task 1: The students, divided in small groups, should set their own experiment, take appropriate measurements and collect data into a suitable table, indicating units and symbols.
Task 2: « Which is the appropriate plotting graph? ». The teacher describes the different types of graphs such as pie chart, bar chart, histograms and line graph and asks the students to provide suitable examples for each type of graph. Student should understand that the type of graph depends on the type of data collected and on the message that they want to convey. Finally, the students should come up with their choice of graph.

2.2.3 Plenary discussion in class (1 hour)

Students should describe the results, comparing and contrasting the data, analysing the graph searching for patterns and trends. Then, they should be able to draw appropriate conclusions, providing suitable explanations, evaluating the procedure and, eventually, suggesting reasonable improvements.

2.2.4 Assessment: filing a lab report

The laboratory report represents the basis for the researcher's activity since it contains all the information required to write a paper for publication. From the CLIL point of view, it represents an example of task with a perfect integration between content and language. In terms of content, subject-specific vocabulary is used and a glossary can be created; in terms of communication, a lot of grammar and lexical structures can be learned or reviewed such as present/past tenses, passive/active forms of verbs, comparatives and superlatives; expression of time (first, second, then, finally, furthermore…) are also highly utilized in filing scientific reports. The text Scientific English by Zanichelli[2] is an useful tool to help students filing a lab report: it provides a guide on the overall structure of the lab report (introduction, materials and methods, results, conclusions and discussion) as well as a detailed analysis of the language used, pointing out the subtle differences between terms and their use in different contexts.

Filing a laboratory report involves the design of the experiment, data collection and processing, conclusion and evaluation, evaluation of manipulative skills (Allott, Mindorff, 2010). For each of these items, the teacher should indicate the assessment criteria as described below:

- ***Design of the experiment:***

- Defining the problem, providing working hypotheses and selecting variables. The student should:
  - identify a focused problem or a specific research question
  - provide suitable working hypotheses
  - identify the independent and dependent variables and control factors

- Controlling the variables. The student should:
  - attempt to maintain the controlled variables at a constant value
  - select the appropriate apparatus
  - select the experimental method
  - if a standard technique will be used, it should be referenced
  - adapt a general protocol provided by a teacher in a previous investigation
- Development of a method for data collection. The student should:
  - decide how to collect data
  - collect a sufficient number of data: if an error analysis involving the calculation of standard deviation, a sample size of at least 5 is needed

- *Data collection and processing:*

- Recording raw data. The student should:
  - attempt to quantify the uncertainties
  - consider the significant figures according to the instruments
  - record raw data in an appropriate table
  - check instructions for drawing
  - indicate magnification and scale bars
- Processing raw data. The student should:
  - elaborate data using mathematical tools
  - transform raw data into a form suitable for graphical representation
  - draw a best fit line where required
- Presentation of processed data
  - decide upon a suitable presentation format (spreadsheet, table, graph, chart, flow diagram….)
  - design an appropriate result table
  - graphs need to have appropriate scales, labelled axes with units (metric/SI units), and accurately plotted data points with a suitable best fit line or curve for plotting graph in biology
  - error bar are not required, but can be included in the graphs
  - include a treatment of uncertainties and errors with their processed data, where relevant

- *Conclusion and evaluation:*

- Conclusion. The student should:
  - compare different graphs or describe the trends shown in graph
  - explain the results describing observation, trends or patter revealed by the data
  - draw a conclusion as to their confidence in the results by comparing the experimental value with the textbook or literature value. The literature consulted should be fully referenced.
- Evaluation of the procedures. The student should:
  - comment on the design and the method used in the investigation (processes, use of equipment and management of time)
  - comment on the quality of the data collected
  - identify and comment the weaknesses in the design and method
  - comment on the precision and accuracy of the measurements
- Improvement of the investigation. The student should:
  - suggest improvements based on the weakness and limitation previously identified
  - suggest any modifications of the experimental techniques and the data range

- ***Manipulative skills:***

- Following instructions. The teacher will assess:
  - the amount of assistance required in assembling equipment
  - the orderliness of carrying out the procedures
  - the ability of following the instruction accurately
- Carrying out techniques. The teacher will assess:
  - the modality in which student deals with the different experimental situations
- Working safely. The teacher will assess:
  - the approach to safety during investigation

For each of the above indicators, the teacher should identify the degree of achievement (« complete », « partial », « not at all ») and assign a score (2, 1, 0):

- ***Defining the problem, providing working hypotheses and selecting variables:***

  - Complete (2) → the student formulates a focused problem and provides reasonable hypotheses; the student identifies the relevant variables and designs a method for the effective control of the variables
  - Partial (1) → the student formulates a focused problem, but does not provide reasonable hypotheses; the student identifies only some variables or designs a method that makes only some attempts to control the variables
  - Not at all (0) → the student does not formulate a focused problem and does not provide reasonable hypotheses; the student does not identify the variables and designs a method that does not control the variables

- ***Collecting data and processing:***

  - Complete (2) → the student records appropriate data and processes the quantitative data correctly
  - Partial (1) → the student records appropriate data with mistakes /omissions or processes the quantitative data incorrectly
  - Not at all (0) → the student does not record any appropriate data or the data are incomprehensible

- ***Drawing conclusions:***

  - Complete (2) → the student states a conclusion *with justification* based on a reasonable interpretation of results
  - Partial (1) → the student states a conclusion based on a reasonable interpretation of results
  - Not at all (0) → the student states no conclusion or the conclusion is unreasonable

- ***Evaluating the experimental procedure:***

  - Complete (2) → the student evaluates weaknesses and problems and suggests improvements
  - Partial (1) → the student identifies only some weaknesses and problems or suggests superficial improvements
  - Not at all (0) → the student identifies irrelevant weaknesses and problems and suggests unrealistic improvements

Notes

[1] Http://nobel.scas.bcit.ca/debeck_pt/science/safety.htm
[2] AA.VV., *Scientific English. L'inglese scientifico per relazioni e conferenze in medicina, biologia e scienze naturali*. Ed. Zanichelli, Bologna, 2007.

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Useful websites

Http://www.bbc.co.uk/schools

Http://www.bbc.co.uk/science/space

Http://www.biotopics.co.uk/JmolApplet/jcontentstable.html

Http://www.breakingnewsenglish.com/ à Go to the Science and Technology Archives

Http://www.cellbio.com/images.html

Http://www.cellsalive.com/toc_cellbio.htm

Http://www.classzone.com

Http://www.copernicusproject.ucr.edu/ssi/HSBiologyResources.htm

Http://www.enchantedlearning.com/Home.html

Http://www.esa.it

Http://www.funsci.com/texts/wsites_en.htm

Http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter2/animation__how_osmosis_works.html

Http://www.nasa.gov

Http://www.nature.com/nature/podcast/index.html

Http://www.onestopclil.com

Http://www.onestopenglish.com

Http://www.phschool.com/science/planetdiary/archive

Http://www.planet-science.com

Http://www.schoolscience.co.uk

Http://www.scienceacross.org

Http://www.science.nationalgeographic.com/science

Http://teach.genetics.utah.edu/content

Http://www.teachernet.gov.uk/teachingandlearning/subjects/science/

Http://www.teachnology.com/teachers/lesson_plans/

Presentazione dell'autrice

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