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Master's Dissertation/ Trabajo Fin de Máster

STEM AND CLIL: A COLLABORATIVE APPROACH BASED ON THE FLIPPED CLASSROOM MODEL

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ABSTRACT

This Master's Dissertation is aimed at designing a teaching unit for Biology in the fourth year of Compulsory Secondary Education, based on the integration of STEM Education and CLIL in a Flipped Classroom. Given the complexity of the proposed scenario, a detailed literature review to contextualise STEM literacy as an emerging education of the 21st century is presented, followed by research focused on the CLIL methodology. Finally, the last part of the literature review is devoted to Flipped Classroom, intended as an active, learner-centred approach that turns the classroom into a practice-oriented space. Cooperative work based on Inquiry-Based Learning and an experimental project is at the core of the learning process where collaboration, group work and scientific research are the key tools for learning both the content and the target language. The proposed teaching unit thus seeks to inspire other teachers keen to put into practice the fundamentals of STEM education in a CLIL environment, where the foreign language plays a central role as a means of communication and learning.

Keywords: *CLIL, STEM, Flipped Classroom, Problem-based Learning, Compulsory Secondary Education.*

RESUMEN

Este Trabajo Fin de Máster tiene como objetivo diseñar una unidad didáctica para la asignatura de Biología en cuarto curso de Educación Secundaria Obligatoria, basada en la integración de la Educación STEM y AICLE en una Clase Invertida. Dada la complejidad del escenario propuesto, se presenta una detallada revisión bibliográfica para contextualizar la Educación STEM como educación emergente del siglo XXI, seguida por una investigación enfocada a profundizar en la metodología AICLE. Finalmente, la última parte de la revisión de la literatura está dedicada a la Clase Invertida, entendida como metodología activa y centrada en el alumno que convierte el aula en un espacio orientado a la práctica. El trabajo cooperativo basado en el Aprendizaje Basado en la Indagación y en un proyecto experimental constituye el eje esencial del proceso de aprendizaje donde la colaboración, el trabajo en grupo y la investigación científica representan los instrumentos clave de aprendizaje tanto del contenido como de la lengua target. La unidad didáctica propuesta pretende así inspirar a otros profesores interesados a poner en práctica los fundamentos de la educación STEM en un entorno AICLE, en la que la lengua extranjera adquiere un gran protagonismo como medio de comunicación y aprendizaje.

Palabras clave: *AICLE, STEM, Clase Invertida, Aprendizaje Basado en Problemas, Educación Secundaria Obligatoria.*

1 INTRODUCTION

1.1 Justification

Today's society is facing new challenges and opportunities that demand professional profiles specialised in problem-solving and being able to face the environmental, social, and economic issues that characterise the evolution of modern society. This fact means that the professions and jobs that are now popular and will increasingly be in demand in the future can hardly be fulfilled with the skills and abilities that ruled the work sectors until yesterday. It is undeniable that the world is advancing technologically by tremendous leaps and bounds, which is why we need to strengthen our students' mathematical, scientific and technological skills without renouncing the essential background in the arts and humanities.

Hence, this is where STEM Education comes in, an educational model that combines the areas of science, technology, engineering, and mathematics, creating an integrative and illustrative method that facilitates learning in these four disciplines. This approach allows students to explore Mathematics and Science through experience, helping them develop critical and creative thinking.

Since recently, STEM literacy has become a priority for leaders worldwide to ensure that their young people can compete in a globalised economy based on knowledge and technology.

In addition to this, there are other priorities determined by the cultural and social evolution we are going through. There is a clear need to train learners with the proper language competences to deal effectively within a multilingual and multicultural society. This challenge, which the educational world has taken up with enthusiasm and initiative, has led to an increasing attention to the Content and Language Integrated Learning methodology as a resource for promoting language learning in the school environment. The Content and Language Integrated Learning (henceforth, CLIL) is defined as a new pedagogical paradigm in which the new language is learned through real-life, everyday situations, actively applying the target language in the study of other common subjects, such as Natural Sciences or History. In other words, CLIL harmonises the study of a subject while promoting the learning of a language. Therefore, given the characteristics and needs of STEM literacy and the principles of CLIL methodology, where both share the urgency of creating a dynamic, creative, stimulating environment using student-centred learning strategies, the Flipped Classroom is the ideal model to meet both challenges. The Flipped Classroom is intended as a didactic approach that puts students at the centre of their own learning process: this entails that students come to class with prior knowledge of the subject and, once in class, they do not receive a master class but put into practice what they have learnt at home through hands-on activities and tasks that facilitate participation and interaction with peers. The method emphasises collaborative and constructive work in the classroom and provides a student-centred approach to teaching. Finally, it establishes differentiated learning roles according to individual student needs.

Hence, this Master's Dissertation (henceforth MD) focuses on creating a didactic unit for STEM disciplines incorporating the CLIL and the Flipped Classroom approach. Besides, Biology and Mathematics will be integrated to achieve their learning objectives through cooperative activities, where the focus will be placed on student-centred methodologies.

1.2 Objectives

The main objective of this MD is the presentation of an intervention plan for STEM education integrated with CLIL methodology. To carry out the proposal, given the specific characteristics of both STEM education and CLIL approach, the Flipped Classroom model has been chosen as a methodology of active and student-centred learning to enhance the benefits of both STEM education and CLIL methodology. Considering the principles underpinning the MD, general and specific objectives can be outlined:

General objectives.

- To introduce STEM teachers to the theory and implementation of CLIL methodology.
- To provide the instruments for the implementation of updated learner-centred methodologies.

- To familiarise teachers with the theoretical principles and implementation of flipped learning.
- To provide STEM teachers with tools and techniques for a STEM teaching unit integrated into the CLIL environment.

Specific objectives.

- To design a flipped STEM proposal integrating student-centred methodologies and CLIL principles
- To provide a template for a STEM teaching unit as a means for future studies to assess the importance of integrating different educational models to improve student achievement and skills.

The MD consists of two main parts: firstly, a theoretical section which includes a literature review that explains in detail the origin, characteristics, and educational approach of STEM Education, CLIL methodology and the role of the Flipped Classroom as a student-centred approach to enhance STEM Education, and secondly the design of the proposal of didactic unit.

2 LITERATURE REVIEW

The literature review includes a first part which delves into the principles underpinning STEM literacy. In the second part, the CLIL methodology will be reviewed, focusing on the importance of CLIL in fostering the learning of content through a foreign language. Finally, in the third part, the Flipped Classroom will be taken as an example of a pedagogical framework in which the methodological principles of CLIL and STEM are developed.

2.1 STEM LITERACY AND STEM EDUCATION

2.1.1 Origins and definitions

In general terms, literacy has been narrowly defined as the ability to read and write. However, the concept of literacy has evolved due to changes in communication patterns and work demands. In fact, according to the Cambridge Dictionary, the definition of literacy (Cambridge University Press, n.d.) refers not only to the ability to read and write but also to the basic competence or knowledge of a subject.

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), literacy has become a key factor for social change, recognised as an educational tool related to inclusion and social justice. To all effects and purposes, it is a fundamental human right, precisely because people would not have equal opportunities in life without it. In contemporary societies - both "developed" and "developing" -economic growth and modernisation of society are such that learning is a life-long process. (UNESCO, 2008). Consequently, the literacy process also requires adaptation as society continues to advance, creating technological advances, social welfare and new knowledge.

Literacy plays an extraordinarily important role in today's world, as it is vital for all kinds of communication and learning and a *sine qua non* for access to today's knowledge society. Literate people are those who are equipped with the tools to develop themselves, personally and professionally. Therefore, literacy in all areas of knowledge must be promoted, as it is the vehicle for achieving successful human development. Moreover, in light of this definition of literacy, it is possible to understand the importance of STEM literacy in each person's life. It should be conceived as an essential tool that enables individuals to cope with their daily activities such as being responsible for their professional and personal growth, as well as with the surrounding environment.

According to White (2014, p.4), the four areas that bring together the acronym STEM are:

- **Science**: knowledge acquired through observation, experimentation and investigation of natural phenomena.
- **Technology**: scientific discipline focused on the study and development of techniques and tools aimed at improving the quality of life.

- **Engineering**: scientific discipline aimed at transforming the knowledge of the pure sciences into real-life solutions for the benefit of humanity.
- **Mathematics**: is a deductive discipline that encourages the use of logical reasoning, the study and practice of which is fundamental to both individual and collective development.

Although the acronym STEM stands for Science, Technology, Engineering and Maths, actually it is also intended to cover areas of knowledge ranging from social sciences to economics (Martín-Páez et al., 2019).

It is necessary to refer to the United States of America to understand how the drive to formalise STEM literacy came about. In its annual report published in 2007, the National Science Board pointed out for the first time that the scientific-technological skills of American students were below the world average. Therefore, it encouraged the urgent need to develop more excellent skills in scientific areas in order to maintain economic competitiveness. In response, the education community reacted, by including for the first time, new learning standards that encompassed the principles of scientific literacy, adding engineering and technology to the science curriculum. STEM literacy is thus intended as a response to the needs of 21st-century society.

In the light of the previous concepts, it stands out how STEM is challenging but essential: it is only necessary to look around us to realise that we are surrounded by STEM. The four branches of knowledge covered by STEM areas involve a wide range of university careers: Medicine, Nanoscience, Web Application Development, Genetics, Chemistry, Nursing, Robotics, Physics, Naval Engineering, Architecture, Mathematics, Electronics or Statistics are just a few examples. These are the areas that underpin the development of the innovations that sustain our lives today.

It is worth reflecting on how in our daily activities, whether for work or leisure, we use technologies and services developed in STEM disciplines and how these tools improve the quality of life. We have access to devices such as smartphones and high-speed internet connections, means of transport, medical instruments that not only evolve thanks to R+D+I (research, development, and innovation) but are a clear indicator of a country’s potential in terms of growth and production.

For this reason, professions related to STEM areas are already of vital importance and will be even more so in the coming decades. In the next future, the profile of the most in-demand and best-paid professionals will be those directly linked to innovation, creativity, critical thinking, collaboration, problem-solving and the application of knowledge to real life. STEM literacy brings greater competitiveness and productivity in a globalised, technology-dependent, and knowledge-based society and is key to economic growth and development. Furthermore, according to some media and experts, STEM jobs will be in high demand in the labour market.

In its annual Flexibility report at the end of 2016, the human resources company Randstad (Randstad Research, 2016) stated that digitalisation would have generated more than 1,000,000 jobs in the following five years, in which STEM professionals would have occupied a large percentage. While companies require professionals who can increase their capacity to generate business in areas related to the digitalisation and automation of processes, the existing profiles in the labour market are insufficient to meet this need. This gap makes Spain one of the countries most threatened by the projected talent deficit between 2020 and 2030, a widespread problem in Europe, except Sweden, Great Britain, and France (Asociación Española para la Digitalización, 2019). Other industrialised countries, such as the United States, Canada, Japan and South Korea, face a similar level of uncertainty. On the other hand, emerging powers, such as Brazil, South Africa, India and China, will find it easier to meet the business needs for STEM profiles in the next two decades.

To complete the analysis of STEM literacy, it is worth considering the problems related to science and the presence of women in scientific fields. In many countries, women are under-represented in the different STEM areas. Nevertheless, they are over-represented in other fields, such as health, psychology, or education. Secondary education is considered a critical stage in which girls begin to distance themselves from science and mathematics (Kahn & Ginther, 2017; Moss-Racusin et al., 2021, Wall, 2019).

The study conducted by Rupérez et al. (2021) mainly aims to examine the relationships between the gender variable, the expectations of 15-year-old students to pursue STEM professions and performance in science in Spain, and finally raises some implications for science education. From the analysis of the study results, there is a systematic difference between students' perceptions of their future STEM careers, as measured by PISA, and the reality of the higher education studies they eventually undertake: in the case of Spain, this gap is 9 percentage points. Therefore, one of the biggest challenges that Spain must address not only encompasses attracting talent to STEM disciplines but also motivating girls to pursue careers in science. In general terms, it will be highly beneficial for Spanish society to have women playing a leading role in the technological and scientific growth of the country. Furthermore, UNESCO (2015), in a series of reports entitled *Science Report: toward 2030*, recognises and warns that, although most students will not become scientists, they still need to master the mechanics that rule the modern world. Some of the goals of STEM literacy are:

1. To foster citizens' participation in social and political choices by knowing how to adapt to a technological society.
2. To prepare those who aspire to a professional career in the scientific field.
3. To prepare students for the challenges of the future
4. To foster the cultural and educational development of the student community.

Fostering STEM literacy is not only fundamental to prepare a more significant number of scientists in the near future but also to create citizens who will benefit from STEM culture in their daily lives. Scientific literacy, therefore, is conceived as an essential skill in the management of one's own personal choices and to be an active part of a country's political, economic, cultural and social life. Content alone is no longer sufficient to achieve these goals, as a wider range of skills must be attained. The development of this new literacy entails considering a wide range of content, be it procedural, conceptual and attitudinal, but most importantly, understanding that the core of the STEM disciplines lies in appreciating the interconnections that exist between them. Thus, STEM literacy is not just the sum of scientific, technological, or mathematical literacy, but is much more than its parts. (Zollman, 2012).

Bybee (2013) reflects on the connection between STEM Education and the global challenges that our society must face and where skills related to STEM disciplines can play a crucial role. The scholar also defines STEM literacy by referring to:

- Awareness, competences, and abilities to identify real-life problems
- To understand the main characteristics of STEM disciplines as part of human learning.
- To recognise how STEM disciplines influence the way we perceive cultural, environmental, and intellectual issues.

- A disposition to relate STEM to responsible citizenship.

To better understand the importance of his words, we can consider as an example the Sustainable Development Goals set by the United Nations (Fig. 1). It is widely known that the United Nations General Assembly adopted a roadmap to identify and address the major challenges facing humanity, such as poverty, climate change, food shortages and the protection of the planet, as well as setting goals such as prosperity, peace and good quality of life for all. These issues have been classified into 17 Sustainable Development Goals (henceforth, SDGs) and collected in the UNESCO's Agenda for Sustainable Development, entitled *Transforming our World.*

Figure 1. The sustainable Development Goals. United Nations

Analysed individually, we can see the close correlation between the SDGs and the skills and competences related to STEM disciplines. Briefly reviewing the most important SDGs, we can mention the SDG 2, which focuses on eliminating hunger and ensuring food security. SDG 3 aims to ensure healthy behaviours and promote access to healthcare for all, such as ending foreseeable deaths of infants and children under the age of five and solving the epidemics of AIDS, tuberculosis, malaria and tropical diseases. SDG 6 is also highly ambitious as it includes ensuring access to safe potable water and its sustainable management.

The mastery of STEM disciplines can contribute to achieving other Sustainable Development Goals, such as SDG 7, which aims to promote renewable energy sources and SDG 12, which pursues to ensure sustainable production and consumption patterns. Likewise, SDG 13 is clearly in line with the STEM disciplines, as it is oriented to tackle climate change. Finally, SDG 15 seeks to protect and restore terrestrial ecosystems, combat desertification, and prevent biodiversity loss.

In addition, both SDG 8 (economic growth) and SDG 11 (sustainable development of cities) aim to improve people's lives efficiently, both in terms of access to employment, modernisation and achieving full and productive employment, as well as ensuring access to safe and affordable housing for all people, strengthening the relationship between the rural and urban world. In both cases, it is undoubtedly clear that STEM disciplines have much to offer. In conclusion, emphasising STEM literacy means providing students with critical thinking and creativity skills to solve global and individual challenges.

2.1.2 Strategies and techniques to establish the STEM Education approach

Given the interdisciplinary nature of STEM literacy with a focus on problem solving, it is possible to conclude that active teaching methodologies seem to be the ideal ones to implement this teaching model, such as problem-based learning, project-based learning and inquiry-based science teaching.

Despite the lack of a fully developed theoretical framework underpinning STEM education, Perales Palacios and Aguilera (2020) suggest guidelines for designing activities to foster STEM literacy in the classroom. According to these authors, the main teaching approach envisages the integration of Science, Technology, Engineering and Mathematics, to a greater or lesser extent, oriented towards solving preferably real problems. The curriculum is focused on generating a STEM identity in students where the social impact of STEM disciplines is highlighted. Throughout the teaching-learning process, the information is also focused on the conceptual, procedural and attitudinal contents of the STEM disciplines. Students play an active role, given that they must search for and analyse information in order to create their own content, while assuming that real problems must be tackled from an interdisciplinary perspective. On the other hand, the teacher's role is to select or design real problem situations, taking into account the conceptual, procedural and attitudinal contents of the STEM disciplines in order to solve them. In addition, teachers set questions to guide learning and make explicit the links between the STEM disciplines, focusing the teaching-learning process on the students.

In the same vein, Domènech Casal (2019) sees Inquiry-Based Learning (henceforth, IBL) as an educational model where students learn science by emulating the investigative process that science follows to create knowledge: formulating an investigative question, designing an experiment, and collecting and analysing the data, then drawing conclusions and formulating an explanation. These are usually laboratory-based activities using simulators and other technologic materials. In addition, according to Duran and Dökme (2016), when comparing the roles of teachers and students involved in IBL, teachers play the role of guide and advisor, while students are the problem solvers following the steps of the scientific method. While in traditional classes, the method foresees lectures and repetition, in IBL, learning is based on solving problems, participating in projects, and conducting experiments. In this way, creativity is also encouraged when it comes to finding original solutions. In IBL, mistakes are part of the learning process, as students also learn from them by rethinking experiments.

This type of methodology is clearly intended to trigger the development of hypothetical thinking in students as well as to encourage creativity. Other types of activities can promote the connection of scientific and technological aspects of topics relevant to students, such as the controversial issues of vaccines and pseudoscience, encouraging the development of critical analysis skills, use of evidence and ethical considerations in everyday life. Finally, STEM activities can delve into issues of sustainability and ecology to help students perceive the global dimension of issues and the components of social injustice that are often associated with them.

Likewise, the Problem-Based Learning (henceforth, PBL) approach in STEM disciplines has undoubted advantages over traditional content-based teaching, especially in motivating students to learn about the world around them through enquiry, exploration and solving real problems. PBL is an active methodology that has three main characteristics (Torp & Sage, 1998, p.16):

- It makes students responsible for a problem situation.
- It organises the curriculum around problems that generate meaningful learning.
- Teachers encourage their students to think and guide them in their investigation to reach deeper levels of understanding.

PBL promotes a deeper understanding of the connections between principles, skills and concepts that interconnect disciplines, helps students experience scientific enquiry, involves collaborative and creative management within the work group, stimulating the exchange of ideas and solutions. Finally, it promotes scientific learning and content retention.

As an example of how such methodologies can be particularly suitable for STEM education, Queiruga-Dios et al. (2021) discuss a STEM project using the PBL connected to the environment outside the school context. The students' surveys highlighted that the project increased their interest in science and technology in general and they experienced science as something practical. Pupils recognise that their communication and teamwork skills have improved and have learned science differently. Implementing a STEM project can often be complicated, especially when involving agents outside the school environment. However, it is satisfying because it favours teamwork, communication, creativity and self-criticism skills.

Likewise, Berry et al. (2012, pp. 226-229) suggest different PBL approaches to propose an integrated methodology for STEM disciplines. The study aims to provide teachers who decide to undertake STEM education in a truly integrated and pragmatic way with models for conducting PBL that offer meaningful science learning.

The first model presented is a teacher-planned approach that integrates different subjects around a central activity. In this approach, the teaching-learning process typically works on two levels: a direct teaching stage, and subsequently, the learner moves into a phase of learning defined as "indirect". During the direct teaching stage, students are traditionally taught with their respective content teachers to ensure understanding of key concepts. Students move on to the indirect learning stage in which, working in groups, they explore and construct their own learning through as realistic challenges and problems as possible. Students are then asked to present their ideas collectively and connect with the knowledge they have learned in the traditional lessons. In this model, teachers can better control the achievement of the school curriculum, although there is still a certain limit to the integration of different subjects.

In the second model, students take a more active role, as they must propose, design and develop their own projects, exploring notions and issues surrounding STEM. These are usually projects developed over time and lead to developing a final product that can be presented to the public. In this model, students have a certain amount of freedom to choose their own project, which makes it particularly interesting. On the other hand, it can be challenging to control a large variety of different projects.

Finally, the authors suggest a third and last model which takes elements from the first two. In this case, each student proposes a project (individually or in a group), and the teacher defines the learning objectives. This model is a highly individualised approach where the teacher acts as a facilitator, monitoring progress and progressively assessing learning. It is certainly an approach which can give excellent results. Nevertheless, it can be challenging because of the initial freedom given to the students, which can lead to the impossibility of completing the project.

All in all, the literature review confirms what Struyf et al. (2019, p. 1387 – 1407) have also evidenced. The authors highlight that STEM Education enhances its role as a student-centred learning environment, specifying four fundamental principles that can guide the design of the STEM approach in secondary education: the application of STEM content through problem-centred learning, inquiry-based learning, solution-design learning and cooperative learning. Besides, when comparing the integrated STEM approach with the classical teaching of science subjects separately (Mathematics, Science, Technology), it turns out that students find it much more enriching and motivating to work with the subjects in an integrated way and with student-centred methodologies than with the classical way of receiving lessons.

Despite all the positive factors that can be highlighted, it is important to stress the difficulty teachers may encounter when designing activities that integrate disciplines that have been led separately until now. There are still doubts about the integration of STEM disciplines, which still creates much uncertainty among teachers. The main concern for teachers is how it would be possible to teach the contents of four different subjects in a complementary way without losing the meaning of each one. In addition, there may be the problem of space and curricular hours that should be devoted to STEM subjects. (Siew et al. 2015, p. 17).

Indeed, it seems that few teachers know how to operate in the field of STEM Education. To solve those doubts, Asghar et al. (2012) analyse the beliefs and feelings of teachers when integrating subjects. Firstly, it should be borne in mind that in secondary education, each teacher is responsible for their own subject and does not always control the content and level of concreteness of the other science subjects. Given this circumstance, the study found that some teachers were dissatisfied with the level of difficulty that other teachers devoted to their own subject, showing a lack of connection and relevance to the curriculum. In addition, many teachers found it difficult to understand the approach's interdisciplinary nature, suggesting that they failed to include engineering in activities centred on biology and chemistry. It turns out that the issue of teacher perceptions is a hot topic, as teacher experience and skills directly influence the quality of STEM education.

Margot and Kettler (2019), analysing the existing literature on teachers' beliefs and the introduction of STEM Education in the classroom, reveal that the more years of experience teachers have, the more they have a favourable opinion of STEM Education. Other teachers highlight insecurity about integrating disciplines they are not familiar with and are concerned about their competence to implement this educational approach. In addition, despite positively valuing the integration of STEM disciplines, other teachers are concerned about the limited communication between teachers from different subject areas. In conclusion, teachers' efficiency, beliefs, and willingness can influence the implementation of an integrated STEM curriculum to a greater or lesser extent, so teachers must receive support and training to carry out this task. The authors conclude by stressing the importance of creating specific training programmes for teachers in order to increase the implementation of the STEM curriculum in the classroom, as teachers need to learn how to become facilitators of knowledge despite not being specialists in all subjects.

Likewise, Bell (2016, p.74) comes to the same conclusion, confirming that teachers' perceptions of STEM have a great influence on the effectiveness of the STEM methodology and its practice in the classroom. The author concludes by stressing the need to train and support science teachers who decide to explore these new ways of teaching so that they can find arrangements with colleagues and advocate for the creation of an integrated and cooperative curriculum for STEM disciplines.

2.2 CONTENT AND LANGUAGE INTEGRATED LEARNING

2.2.1 Origins and characteristics

The author David Marsh was the first to introduce in 1994 this new linguistic approach in language teaching, a methodology currently known as CLIL, providing the following definition: CLIL refers to a teaching methodology where the subject content is taught in a language other than the native language. This methodology is composed of a dual approach because the foreign language is both the vehicle and the object of teaching, alongside the subject content, and both are always accommodated. (Marsh, 2003).

Nevertheless, the CLIL approach is not the first to be based on content-based language teaching. The origin of the CLIL methodology refers to the first language immersion experiences developed in Canada in the 1960's in the Quebec region for English-speaking children who needed to learn French, the dominant language in Quebec. As Genesee et al. (1985, p.28) state, these immersion programmes showed that English-speaking pupils achieved a high degree of linguistic proficiency in French, even more than in cases where French was a subject of study. In the 1990s, CLIL methodology aroused more and more interest precisely because it is based on the importance of employing a non-native language as a vehicle for communication in class and is oriented towards using the language as it is acquired (Martínez, 2019).

Following the Canadian experience, European Union policy makers, who were already attempting to promote second language acquisition among young people in Europe, saw the CLIL model as a possible strategy to achieve this purpose. Therefore, the European Commission has repeatedly encouraged and supported the relevance of CLIL in the language learning process through several policy documents dedicated to the initiative (European Commission 1995, 2003, 2008, Eurydice 2006). The European Union has also, in this regard, promoted and funded programmes for the dissemination and development of CLIL through specific teacher training programmes, material design and research. According to Cenoz et al. (2014), the development of CLIL methodology in Europe has considerably increased the number of hours devoted to a foreign language in school curricula, making the study of languages a key objective.

Moreover, Hanesová (2014) stresses that the richness of CLIL lies in motivating learners and ensuring that language learning happens naturally, creating a context where learners can enjoy learning new content while improving their proficiency in the target language.

Looking deeper into teaching practice, in order to fully understand how to implement CLIL methodology, it is essential to analyse the role of the teacher, given that both subject-specific knowledge and language skills must be taken into account. However, there is still some concern about how to balance the two aspects and how effective CLIL teachers should consider multiple factors so that their classes are not reduced to mere translation.

As Dalton-Puffer (2011) argues, teachers are often not native speakers of the vehicular language, as they are content teachers specialised in their subject: this means that these teachers must have language qualifications that match the class's linguistic needs and the CLIL methodology's linguistic purposes. Likewise, Vilkancienė and Rozgienė (2017), in a study planned to analyse the skills and competences of CLIL teachers, underline that, despite the positive view of the CLIL approach, one of the weakest points that teachers claim is the ability to balance their own and their students' language needs. In contrast, a wide range of language skills is needed: academic language and language for classroom management and interpersonal language skills.

In general terms, to create conditions for the successful implementation of this innovative approach, CLIL must include a comprehensive selection of educational tools and resources, provided that CLIL teaching practice requires teachers capable of demonstrating multiple skills, not only pedagogical skills but also collaborative and interpersonal skills.

As stated by Coyle (2007), CLIL is versatile. Therefore, it is possible to adapt the methodology to a wide variety of contexts. The main features of CLIL require the integration of various techniques, which can be very challenging for teachers. Those traits can be categorised as follows:

- Variety of approaches

- Creative and stimulating environment
- Authenticicty
- Meaningful learning
- Cooperative work
- Teacher as facilitator

Hence, putting all the principles of CLIL methodology into practice is the biggest challenge facing teachers who choose to work in a CLIL environment. Each of the main features fosters the integration between communication, culture, cognition and content: task-based activities, cooperation with language teachers, access to authentic materials, creating connections between learning and students' lives, using materials from media and other sources are all tools that make CLIL a valuable instrument for balanced learning between language and content. Briefly, the central core of the CLIL approach is that where learners can construct their own knowledge through their cognitive skills, consequently it is of paramount importance that teachers implement a variety of strategies in order to stimulate real interactions, critical thinking, interest, especially through activities that engage students in an active learning process (Hanesová, 2014).

For this reason, in the publication *The European Framework for CLIL Teacher Education* (Martin, 2011), among the professional aptitudes that a CLIL teacher should acquire are identifying appropriate content and providing resources to stimulate language learning as well as subject content. According to the authors, an effective CLIL teacher can apply strategies to reinforce critical thinking about language and content. Finally, the CLIL teacher is an agent who fosters cooperation among colleagues and cooperates with them to improve the teaching-learning process.

2.2.2 The 4Cs framework

The boundaries of CLIL methodology are difficult to determine. However, its structure is founded on four main pillars, theorised by Coyle (2010) and defined as the theoretical 4 C's framework (fig. 2). The 4Cs framework for CLIL aims to connect the four pillars of comprehensive learning that stems from content and connects to the other three areas of knowledge: communication, cognition and culture. It is widely recognised that these four areas are essential for the full cognitive development of pupils, therefore the theoretical framework is proposed as a tool to deal with them in a synergetic way.

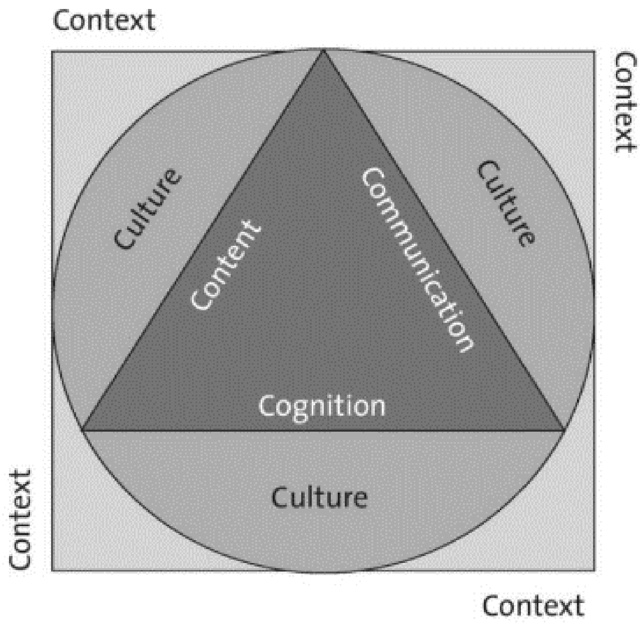

Figure 2. The 4C's Framework. Coyle et al. (2010)

Teachers who decide to follow the CLIL methodology must therefore be able to incorporate a certain variety of ideas into their daily teaching practice, such as considering content as the backbone of language learning and knowing that language is both an object and a vehicle for learning. Teachers, while preparing the material, should ensure that the material also integrates language skills. It will also be essential to use the support of ICT to design visual and auditory teaching resources to facilitate learning. Teachers who decide to venture into CLIL methodology should make sure to include all four elements for a well-designed CLIL lesson:

- **Content** refers to the subject matter, retention of new knowledge and understanding of content.
- **Communication** is the basic instrument for group interaction and a vehicle for learning. Learners are encouraged to use the foreign language to communicate and to learn.

- **Cognition** requires stimulating higher-order thinking processes, such as promoting challenges and problems in order to reach answers and solutions.
- **Culture**: one of the pillars of CLIL is interculturality; therefore, the teacher will seek to emphasise the students' cultural development and European awareness.

2.2.3 The Language Triptych, BICS and CALP

In a CLIL context, the use of language serves different purposes, presenting a variety of aspects. In CLIL methodology, language is both an object of study and a means of transmitting content. In addition, in a CLIL setting, the target language is also the tool for classroom interaction. Under such conditions, both students and teachers need to identify the different functions of language since the CLIL methodology aims to improve language skills in all three aspects, making language learning occur naturally.

In order to systematise and assess the three perspectives of language in a CLIL classroom, Coyle et al. (2010) have developed a scheme that visually synthesises the three characteristics, known as the Language Triptych (Fig. 3), which proposes a theoretical framework for foreign language use from three interrelated points of view, to help the agents involved to develop awareness within the process of language learning and how it is employed in different contexts.

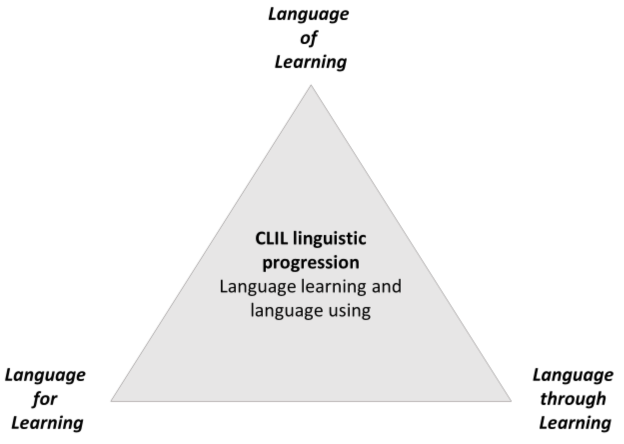

Figure 3. The Language Triptych. Coyle et al. (2010)

The language *of* learning is defined as the language for understanding concepts in the field of knowledge. Depending on the discipline, it can include a vast variety of vocabulary.

The language *for* learning is defined as the language used by the learner to participate in a foreign language environment. It includes both language for social relations and academic language.

The language *through* learning is defined as the language that is generated by learning new elements in the learning process. As new concepts are learned, the related language is assimilated.

The conceptual framework of the language triptych also offers the opportunity to consider two classes of language competencies, the Cognitive Academic Language Proficiency (henceforth CALP) and the Basic Interpersonal and Communication Skills (henceforth BICS). Teachers who work in bilingual contexts are expected to handle both situations in order to achieve a successful learning process. In fact, the two areas are complementary, where the first, CALP, is dedicated to academic and formal language, related to the content. In contrast, the second, BICS, is related to informal language and group communication skills. Martín del Pozo (2016) proposes a scheme to relate the purpose of language according to the language triptych and the communicative skills (Table 1).

Understanding the duality that interconnects CALP and BICS is a central focus of CLIL methodology. Indeed, the pedagogical implications shed light on identifying needs in terms of language skills to be developed. In table 1, it is thus possible to identify what belongs to the sphere of each language area according to the linguistic triptych. Hence, Language *of* learning includes all those linguistic competences relating to academic language (CALP) and subject content. Within Language *for* learning, they are considered all those skills that enable the learner to interact with others and at the same time to maintain a dialogue in relation to the content. In other words, this linguistic sphere encompasses both interpersonal language skills (BICS) and academic language (CALP). Finally, the author considers that Language *through* learning is the language that is learned as a result of the overall learning process and consolidated as the learner progresses. According to the author, the proposed scheme can be a helpful tool for both language and content teachers working in a bilingual environment to self-assess their own communicative skills. The scheme can be used as a checklist to check whether they meet the language skills required for working in a CLIL environment.

TRIPTYCH	CONCEPTS	NEEDS TO MASTER	CONTENTS
of learning	subject-specific language	**CALP** communicative skills and proficiency, which belong to formal and academic language	Specific terminology formal structure academic language
for learning	language appropriate for communicating in the learning setting	**BICS** communicative skills and competences that enable communication among peers and that belong to informal language. **CALP** communicative skills and proficiency, which belong to formal and academic language	functional language for group and subject-related communication
through learning	incidental learning of the new language	Informal expressions	Not predicted language as an instrument for learning

Table 1. BICS and CALP skills

(Martín del Pozo, 2016)

2.2.4 Bloom's Taxonomy: HOTS & LOTS

Once the theoretical foundations have been identified, it is necessary to reflect on the objectives proposed by the CLIL methodology, specifically the results that students should achieve throughout the teaching-learning process. To this purpose, Bloom's taxonomy (fig.4) is the best tool to assess these results. Bloom's taxonomy aims to classify and hierarchically order learning objectives, being a pedagogical tool suitable for preparing lessons with appropriate content in relation to the cognitive domain categories. (Borg, 2003). Furthermore, it is possible to use Bloom's Taxonomy to proceed with students' formative and summative assessments, design teaching strategies calibrated to the learners' real skills, and enhance higher-order skills, such as conceptualising, synthesising and analysing. (Sami & Arumugam, 2020).

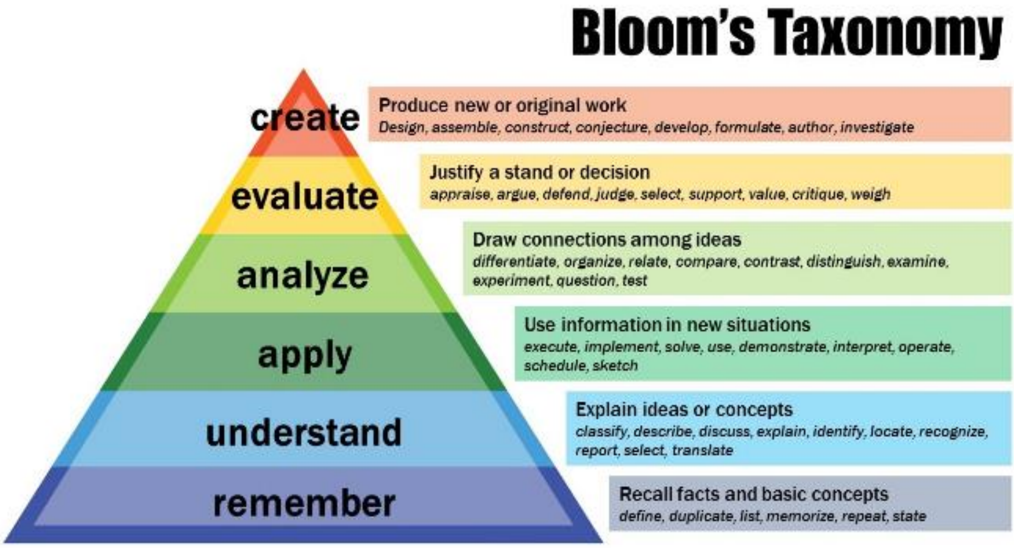

Figure 4. Bloom's Taxonomy (1956)
https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/

In order to understand Bloom's taxonomy chart, it is essential to be aware of the following:

- It is a system of educational classification.
- It does not express content but rather the skills that the student demonstrates.

- It is hierarchical: it means that the higher levels indicate that the lower levels have been acquired.

Bloom's taxonomy divides cognitive skills into blocks where the learner begins from a low level of complexity (low order thinking skills, LOTS), such as remembering, understanding, and applying. It moves up the level of complexity to ever more complex skills such as the ability to analyse, evaluate and create (high order thinking skills, HOTS). Hence, Bloom's taxonomy is generally used to develop learning objectives and as a basis for course design and assessment. It is also a helpful tool for assessing student performance (Crowe et al., 2008). Likewise, according to Adams (2015), Bloom's taxonomy focuses on cognitive learning and is particularly interesting because it helps teachers outline the skills and abilities they want students to master.

2.2.5 Scaffolding in CLIL

The idea of scaffolding is integrated into the CLIL methodology. Students are faced with a great challenge, namely studying both content and a non-native language, where the latter is the vehicle of instruction. Therefore, scaffolding is constituted as an operational tool, inspired by the Vygotskyan notion of the Zone of Proximal Development (Wells, 1999), which designates the layout offered by the teacher to the students to anchor their new learning. This support is eliminated later once learning has been achieved in collaboration with a more expert individual. Scaffolding thus consists of anything that can be used to support learners' independence in their learning process, which will be removed little by little as the learner's autonomy increases. (Fernández-Fontecha et al. 2020).

Mahan (2020), in his study, investigates how teachers scaffold their lessons to help their students understand the content. The author concludes that the most used strategy consists of helping students connect new content to prior knowledge, using supporting materials and defining academic language.

Generally, the nature of the scaffolding to support the learners may vary depending on their needs. Therefore, according to Mehisto (2012, p.24), the teacher must consider different variables: it will be necessary to scaffold the language, for example, using short sentences, synonyms, explaining key concepts. The content should also be supported by using tools such as graphic organizers, videos, and online dictionaries. Finally, cognitive skills also need support: the teacher can acknowledge the student's good work or comment on how it could have been improved, as well as offer an evaluation rubric before starting an assignment.

2.3 FLIPPED CLASSROOM APPROACH

2.3.1 Pedagogical Framework

The Flipped Classroom (henceforth FC) model is an approach that has become increasingly important in recent years because it combines the pillars of modern education such as student-centred learning and technologies in the classroom. FC is a pedagogical approach where the time and space devoted to theoretical and practical instruction are reversed: in other words, students will spend time at home following video lectures with the planned contents, while once in class, they will have the opportunity to practice active methodologies in a dynamic environment in order to understand the contents better. In the Flipped Classroom, the teacher configures the classroom as a space where students learn through hands-on tasks and are creatively engaged in the subject matter. (Alexander, 2018). Hence, as the scholar explains, the FC approach fully represents student-centred methodologies, as students are given learning material to study at home. Once in class, they can dedicate this time to collaborative and more active tasks, unlike traditional methodologies where students are required to complete exercises and assignments at home. This active learning in the classroom focuses on higher-level skills such as creating, analysing and evaluating, hence, implementing the principles previously illustrated in Bloom's taxonomy. In other words, the FC is presented as one of the most suitable methodologies for teachers to foster higher-order cognitive skills in their students.

The FC model reverses the teacher's traditional roles and the lecture as the centre of learning in class, shifting this stage out of the classroom and basing it on videos or other IT media that students can watch at home. Consequently, in-class time is allocated to doing exercises, research and projects with the teacher as the facilitator of learning.

This learner-centred approach reinforces the intellectual skills required of learners, increases motivation and deep learning of both the content and the language used. Learning is made meaningful but stimulating because it is based on interaction, problem-solving, and group work.

Barnes (1989) defines the characteristics of active learning where the FC model is situated:

- Purposive: the relevance of the task for the learners
- Reflective: learners reflect on what they have learnt.
- Negotiated: learners and the teacher must negotiate about learning objectives and learning methods.
- Critical: learners learn different ways and tools of learning the content.
- Complex: students learn to deal with tasks that reflect real-life complexity.
- Engaging: tasks reflect real life; therefore, they are stimulating.

2.3.2 Strategies and techniques to establish the FC environment.

To start with, there are four indicators to identify that a real, inverted class is taking place: Firstly, students work actively and will therefore be more likely to enjoy and retain what they learn. Secondly, personal relationships between classmates and with the teacher are strengthened. Moreover, activities can be adapted to suit the learning style of students. Finally, students become enthusiastic about what they study and to achieve meaningful learning it is advisable to offer activities for which they can choose (Lo et al. 2018 p.161-162).

In addition, Alexander (2018) outlines the positive relationship between the FC setting and Bloom's taxonomy of cognitive learning objectives. The author considers that the FC model meets the principles of Bloom's Taxonomy since students, during class time, are challenged to perform higher-order skills, as well as work in groups and apply collaborative and cooperative strategies. When comparing where and how the cognitive skills assessed in Bloom's taxonomy occur, it is possible to observe that in the traditional teaching model, the learner is expected to develop the higher-level cognitive skills autonomously at home. At the same time, school time is devoted to the less demanding skills. On the contrary, according to the author, more demanding skills are developed in class through the FC model, thereby improving the student's performance.

Through the literature review, it is also possible to appreciate the FC approach's valuable contribution to STEM Education. Wei et al. (2020), in their research on the effects of Flipped Classroom on mathematics performance in secondary school, state that students who participated in it performed significantly better than those who followed traditional classes. Some students stated that taking notes by watching the videos helped them think deeply due to the opportunity to watch the video as often as they needed to, and once in class, the teacher had more time for interactions.

In a study conducted by Porcaro et al. (2016) on the performance of haematology students, it is reported that not only do students who did not pass in traditional classes pass their exams successfully, thanks to the FC approach, but in general, the students' perception of the teacher is much more positive. The environment is more enjoyable and dynamic: students feel more comfortable because they can devote more attention to what really interests them, namely the discussion of case studies during class time.

According to Fung (2020), the FC model can thus enhance STEM Education and overcome many problems that make STEM education challenging to perform. Since STEM Education is based on practice and FC entails moving the theoretical part out of the classroom, class time can be devoted to meaningful collaborative work. The introduction of flipping ensures that more discussions and feedback can be given in class.

The FC model also proves to be effective in practical computer lab sessions. In a study conducted by Troya et al. (2020), where theoretical explanations occupy between 14 and 50% of the time, leaving little space for hands-on tasks, it has been investigated how the implementation of FC increases the time dedicated to practical tasks, thus increasing students' performance and motivation. The study confirms that 89% of the students have watched the videos before coming to class, appreciating the possibility to watch the videos as many times as necessary.

Similarly, Blair et al. (2016) investigated whether the introduction of the FC setting improved the performance and perception of mechanical engineering students. The study confirms that the model is much more interesting and motivating as it is primarily conducted by putting theoretical knowledge into practice, which improves content acquisition. In addition, collaboration, problem-solving skills and motivation are positively influenced. Likewise, Cakiroglu et al. (2020) have concluded that FC increases students' motivation and improves technical skills in the laboratory, facilitating the acquisition of related concepts.

Shifting to another context where the FC approach has been shown to be effective and valuable, many authors affirm that this approach enhances and also sustains the language learning process. Moreover, Fielden Burns et al. (2020) recognise that basing language classes on the FC model not only improves skills in all areas (grammar, listening, reading and speaking) but also the students' overall motivation. The FC approach effectively promotes competence and autonomy as students are actively involved in learning the content at their own pace. Given that many classrooms in Europe are currently considering enhancing language learning with the integration of content according to the CLIL approach, the FC methodology is shown to be effective in assimilating content, whether a language or a particular subject. As shown, Flipped Classrooms promote greater learner autonomy and investment and are student-centred, which is helpful for language students whose levels are rarely homogeneous.

According to Aghaei et al. (2020), students reported that the FC model was particularly beneficial and motivating for language learning. In the same way, the learners have highlighted how the material offered has allowed them to study at their own pace. In class, they have positively valued the possibility of improving their language skills with the support and correction of the teacher. The study shows that in a flipped environment, the teacher pays more attention to each student, whereby progress can be monitored more effectively.

Likewise, Tadayonifar and Entezari (2020) have concluded that student performance has improved significantly after implementing the FC model, specifying that 25% of these achievements are directly related to this new strategy. Such results confirm that the FC approach is more engaging and challenging, significantly improving students' learning process.

The benefits of the Flipped Classroom approach have also been investigated concerning student perceptions. Hew et al. (2020) state that compared to students in traditional classes, flipped classroom students enjoyed the opportunity to learn at their own pace, thanks to the availability of video lectures. In addition, flipped classroom students have benefited from more peer-assisted learning and more time for teacher feedback and support.

The literature review thus shows that FC is a method that offers significant advantages, the first of which is the saving of teaching time. The use of videos provides advantages such as watching the videos as many times as necessary. Among its disadvantages, it is worth mentioning that it probably requires a considerable workload on the part of the teacher to create videos and materials and a certain aptitude for new technologies, which can be overwhelming also for the more enthusiastic teacher.

However, as shown in these pages, the advantages of Flipped Classroom learning are undeniable:

- Maximising learning through engaging hands-on tasks
- The student can watch the videos as many times as he/she wants
- The teacher spends more time guiding his or her students by giving immediate feedback.

In a nutshell, the success of FC highlights that it is necessary to keep updated with any innovation and to be encouraged to apply new methods that go beyond a traditional class. These new methods prepare students to face the real world, where they can apply without difficulty the knowledge that in many cases is forgotten or does not reflect society's complexity.

2.3.3 ITC for implementing the Flipped Classroom

To ensure that the FC model is effective and functional for its purpose, teachers need to be familiar with an extensive range of online platforms and multiple digital devices, both for creating materials for students and their use in the classroom. García de Oliveira et al. (2014) have analysed a series of ICT tools to improve the implementation of the FC model, adapted to the educational context and oriented to the optimization of the learning process. Some of these tools are commonly used by students, such as *Google Drive*, *YouTube* and *Facebook*. Therefore, their integration into the school routine can bring great benefits to students. In the FC approach, the use of certain ICTs is essential and therefore, Artal Sevil et al. (2017) have identified a series of digital educational tools that facilitate students' learning and improve their performance, such as *Socrative*, *Kahoot, EdPuzzle* or *Evernote*. The aim of these applications is to give greater prominence to the educational process, increasing motivation and participation.

Furthermore, according to the authors, the applications have thus facilitated the efficiency of face-to-face classes and collaborative work.

All in all, new technologies have important advantages and are of great significance in facilitating students' autonomous work, maintaining learners' attention and being able to adapt to different learning paces. García-Valcárcel et al. (2014) also emphasise the motivational power of technologies, also highlighting the sense of responsibility in the students themselves, which is positively affected thanks to the integration of new technologies.

3 LESSON PLAN: A FLIPPED STEM DIDACTIC PROPOSAL

3.1 Justification

This didactic proposal arises to meet the needs of science teachers who are eager to start working in a FC environment and are looking for a structure that adapts to the individual learning processes of each of their students as well as to comply with the established curriculum. The approach, with respect to the traditional classes, seeks to:

1. To increase the number of practical hours, which is sometimes completely lacking in a subject like biology.
2. To encourage creativity and real problem-solving, as the proposed activities are inspired by the climate crisis we are currently facing.

The didactic unit presented is adapted to the following regulations:

- Organic Law 8/2013, of 9 December, on Education (LOMCE).
- Royal Decree 1105/2014, of 26 December, which establishes the basic curriculum of Compulsory Secondary Education and the Baccalaureate.
- Decree 87/2015, of 5 June, of the Consell de la Generalitat Valenciana, which establishes the curriculum and develops the general organisation of Compulsory Secondary Education and the Baccalaureate in the Valencian Community.

- Order 38/2017, of 4 October, of the Department of Education, Research, Culture and Sport, which regulates the assessment of Compulsory Secondary Education, Baccalaureate and Adult Education in the Valencian Community.

3.2 Contextualization

The school where the subject will be taught is a public secondary school located in Albal, a city in the Horta Sud district, situated to the Valencia southern area. The school has a total of 1500 students and a teaching staff of 160 teachers, 70% of whom are permanent. The school is very spacious, and its facilities are relatively recent. It has laboratories with enough material to carry out simple practices, and there are two computer rooms available for students. Each classroom is also equipped with a digital whiteboard, a projector, and a desktop computer with an Internet connection.

The group is a class of the 4th year of compulsory secondary school and consists of 20 pupils aged 16, 12 girls (60%) and 8 boys (40%). The group has been in the CLIL section since the first year of Secondary School and therefore has generally B1/B2 level of English. They tend to be a group where they work well and are motivated and interested in science.

3.3 Objectives

Teaching objectives are defined as the results to be achieved during the teaching-learning process at the end of a teaching unit. In this teaching unit, the contents of two different science subjects, Biology and Mathematics, have been intertwined to apply the learning of different contents at the same time and use the same tools. Consequently, the objectives encompass both disciplines simultaneously, where the contribution of one influences the achievement of the other.

At the end of this didactic unit, the student will know how:

- To identify and recognise the environmental factors that influence the life of living beings.
- To describe the structure and components of an ecosystem
- To identify real ecological problems and apply statistical concepts to solve a problem.
- To know how to interpret statistical studies based on ecology.

English is not only a vehicle for communication but also an object of study; therefore, the **language objectives** are:

- To understand the foreign language related to scientific concepts such as ecology and statistics.
- To read texts, instructions, and laboratory techniques.
- To know how to develop a written and oral production about scientific contents.

3.4 Learning standards, assessment criteria and key competences

Assessment criteria describe what students should achieve throughout their learning process, both in terms of knowledge and competences. Likewise, the learning standards are defined as those skills and competences that the learner demonstrates to have achieved at the end of the didactic unit. They specify in detail the assessment criteria and must be measurable and assessable. Each assessment criterion can be specified in one or more standards. Furthermore, the key competences are a fundamental element and represent the integrative synthesis of all the curriculum elements through which it is intended to achieve a comprehensive development of the student. In this didactic proposal, it has been tried to work on as many competences as possible.

According to Royal Decree 1105/2014, of 26 December, which establishes the curriculum for Compulsory Secondary Education and Baccalaureate, the seven key competences have been incorporated into the didactic proposal in the following way:

- **Mathematical Competence and Key Competences in Science and Technology (CMST):** it is the heart of the didactic proposal where students will experience the scientific method by observing, taking measurements, comparing data, and creating their own hypotheses.

- **Digital Competence (DC)**: ICT is an excellent tool for learning which aims to enhance the skills to search for and obtain information, as well as to use different resources to communicate the knowledge learnt.

- **Social and Civic Competences (SCC)**: this competence enables people to live in society and understand the world's social reality. This competence will be worked on throughout the group and cooperative work that permeates the didactic proposal.

- **Competences in Linguistic Communication (CLC)**: in a CLIL environment, language is not only a vehicle for communication but also the object of the learning process. Therefore, we will look for clarity and correctness in the students' expression, and we will create a glossary to reinforce the language acquired.

- **Competence in Learning to Learn (L2L)**: to foster this competence, it is indispensable to awaken curiosity in order to understand natural phenomena. Therefore, we will work through IBL with questions that engage curiosity.

- **Cultural Awareness and Expression (CAE)**: we will work on this competence through the culture of care, in other words, taking care of our environment in order to take care of people.

- **Sense of Initiative and Entrepreneurship (SIE)**: we will work on the students' entrepreneurial spirit through research and project planning, encouraging them to discover their own vocation.

This didactic proposal stems from the curriculum of the subject Biology and Geology for the fourth year of Compulsory Secondary Education, where contents, learning objectives, assessment criteria and key competences from Mathematics have been integrated (Tables 2 and 3).

SUBJECT	CONTENTS	ASSESSMENT CRITERIA	LEARNING OBJECTIVES	COMPETENCES
BIOLOGY	Environmental factors	Recognise the environmental factors that condition the development of the living organism in each environment	Categorise environmental factors and their influence on living beings	CMST CLC DC L2L
	Adaptation of living beings	Compare adaptations of living beings to different environments	Describe the structure and components of the ecosystem	L2L DC SIE SCC
	Population ecology	Recognise the influence of endogenous and exogenous factors in the regulation of populations	Apply the concepts of carrying capacity, birth rate and mortality rate of a population	SIE DC L2L
	Experimental skills and scientific method	Search, identify, select and interpret scientific information	Interpret the adaptations of living organisms to a given environment	CMST DC L2L

Table 2. Biology curriculum

SUBJECT	CONTENTS	ASSESSMENT CRITERIA	LEARNING OBJECTIVES	COMPETENCES
MATHEMATICS	Statistical variable and frequency tables	Develop mathematical processes based on the identification of problems in real-life contexts	Identify problematic situations likely to contain problems of interest	CMST CLC DC L2L
	Statistical graphs	Develop and cultivate personal attitudes inherent to mathematical work	Represent graphically mathematical data by employing the most appropriate technological tools	SIE CLC
	Dispersion and correlation diagrams	Solve different situations and problems of everyday concepts by applying probability calculations	Interpret a statistical study based on a concrete situation	CMST L2L DC CAE SCC

Table 3. Mathematics curriculum

Likewise, English is not only a vehicle for linguistic communication but also an object of study. Consequently, the contents to be achieved during the didactic unit are presented below (Table 4).

SUBJECT	CONTENTS	ASSESSMENT CRITERIA	LEARNING OBJECTIVES
ENGLISH	Ecology-related vocabulary: ecology, population, biotic and abiotic factors, risk factors, ecological threats, inter and intraspecific relationships, adaptation Mathematic-related vocabulary: statistical graphs, measures of dispersion, position	Listening skills: identifying relevant information in oral texts, both on video and in-class communication. Reading skills: extracting the most important information from written texts and understanding scientific words. Production of oral and written texts using appropriate scientific language.	Express existence Express quality Express quantity: regular and irregular plurals; cardinal and ordinary nouns; adverbs of quality Affirmation/negation: affirmative and negative sentences Questions: direct and indirect questions

Table 4. English STEM contents

3.5 Methodology

The didactic methodology includes all strategies, procedures and actions based on a series of pedagogical principles, aimed at organising the teaching action. By using an active and stimulating methodology, employing methods that encourage students to participate, investigate, and work cooperatively in teams, we foster critical reasoning, as the didactic proposal developed in this MD is intended to do.

In order to carry out this didactic proposal, the following aspects have been considered:

- Promote the construction of meaningful learning by making the content interesting and useful for the student's life.
- Motivate and encourage students' interest.
- Promote collaborative work and interaction between students.

Given the conditions of working in a CLIL environment integrating the STEM disciplines, further factors need to be considered when designing an effective methodology, both to ensure that subject content and language resources are tailored to the learner. Likewise, as scaffolding measures, the following pedagogical tools are foreseen to be used:

- Activation of subtitles and a written text to support the video lectures
- Presentation of complex words through images
- Use of short sentences and various synonyms
- Repetition of the words with correct pronunciation
- Computer applications and online vocabulary

Classroom activities are also focused on different objectives:

- Initial activities to activate prior knowledge and motivation.
- Targeted IBL and PBL activities will be the main ones calibrated from less to more complexity.
- Consolidation and synthesis activities to reinforce what students have learnt.
- Evaluation activities in order to assess the learning process.

For students to work correctly, they will have at their disposal a wide variety of digital resources, such as videos, self-checking tests, documents, bibliographic resources, all gathered in a single platform, Edmodo. In class, each group will have a tablet at their disposal to work properly during the activities. Likewise, students are also allowed to use their smartphones to carry out research. ICT activities will be carried out at home and in the computer lab, while the rest will take place between the classroom and the biology lab.

3.6 Edmodo Platform

The virtual platform is a fundamental instrument to carry out the FC approach properly. Among the many platforms available, I have chosen Edmodo (ANNEX I) for its structure and the presence of sections and folders where the material can be catalogued. Once the students have had access to the platform, they can communicate through a common forum with their classmates and the teacher, upload and download material and perform the tasks. In order to make it easier for students to navigate the platform, a calendar of the didactic unit has been created so that students may know the content of each session. Besides, different folders based on the content have been created:

- ✓ Video material
- ✓ Resources to carry out the PBL
- ✓ Material to perform the IBL
- ✓ The reinforcement tasks
- ✓ The extension tasks
- ✓ The evaluation rubrics.

In addition, the stable groups are already present where each member will have access to upload or download the material.

3.7 Multidict platform

The video material offered to the students must be of high quality since it represents the master class that the student must study in autonomy when the FC model is used. Since in a CLIL environment, the language used is English, it is not always easy to find appropriate videos on platforms such as YouTube or Vimeo, so that the teacher may have to prepare their own material. To overcome this problem and offer my students a suitable scaffolding tool, I decided to upload the chosen videos on the Multidict platform (ANNEX II), a free and intuitive tool funded by the European Union's Erasmus+ Programme. Here, the teacher manually adds the text of the video and selects the language from the associated dictionary. The student can then read the text while listening to the video and use the dictionary by clicking on the word in the text.

3.8 Attention to diversity

Educational response measures for inclusion and attention to diversity are necessary to ensure inclusive, equitable and quality education for all learners. In this didactic unit, I have considered implementing activities and different materials and resources to be used flexibly. These actions will increase motivation and take into account different preferences, interests and learning rhythms. I have privileged group work, paying special attention to distributing tasks and encouraging mutual help among students. In addition, there will be complementary explanations, and a simplification will be offered in the case of very complex tasks.

3.9 Sessions

This didactic unit includes two sections, which represent the essence of the didactics according to the principles of the Flipped Classroom, namely, to reverse the space and time spent on learning content and the one devoted to exercises: the first will be done at home, studying videos and carrying out short self-assessment exercises, while the part of practical exercises will be done in class, collaboratively with the rest of the classmates. In the first session, it is crucial to explain the importance of doing the proposed tasks at home, given that in class we will be working on these contents. It is foreseen that the in-class sessions will be composed of 12 sessions of 50 minutes each. Throughout the didactic unit, the class will participate in two types of activities, the PBL (ANNEX III) and IBL, called the Mesocosm Experience (ANNEX IV). The last session will be devoted to the final exam (ANNEX V). Tables 5 and 6 below show the planning of the out-of-class and in-class sessions.

<table>
<tr><th colspan="2">SESSION 1. Overview of the Flipped Classroom approach</th><th colspan="2">SESSION 2. The Mesocosm Experience begin</th></tr>
<tr><td>Description</td><td>Students must watch the videos and complete the tasks assigned on the Edmodo platform.</td><td>Description</td><td>Students must watch the videos and complete the tasks assigned on the Edmodo platform.</td></tr>
<tr><td>Contents</td><td>Digital learning
ecology principles
the experimental model</td><td>Contents</td><td>Environmental factors
biotic and abiotic factors</td></tr>
<tr><td>Materials</td><td>The Scientific Method
Ecology: terminology</td><td>Materials</td><td>How to build a mesocosm</td></tr>
<tr><td>Activities</td><td>Terminology: reinforcement activity
Ecology test review nº 1 on Edmodo</td><td>Activities</td><td>Ecology test review nº 2 on Edmodo</td></tr>
<tr><th colspan="2">SESSION 3 and 4. Problem nº 1. What is an ecosystem and how does it work?</th><th colspan="2">SESSION 5 and 6. Problem nº 2. The threat of invasive species</th></tr>
<tr><td>Description</td><td>Students must watch the videos and complete the tasks assigned on the Edmodo platform.</td><td>Description</td><td>Students must watch the videos and complete the tasks
assigned on the Edmodo platform.</td></tr>
<tr><td>Contents</td><td>Structure and components of an ecosystem
relationships and external influences</td><td>Contents</td><td>Population ecology
birth rate and mortality rate of a population
invasive species</td></tr>
<tr><td>Materials</td><td>What is an ecosystem
Biotic and abiotic factors
Human impacts on biodiversity</td><td>Materials</td><td>Population ecology
Invasive species</td></tr>
<tr><td>Activities</td><td>Habitats and niches: reinforcement activity</td><td>Activities</td><td>Food Chains: reinforcement activity
Ecology test on Quizizz
Online simulation on Phet Colorado</td></tr>
</table>

SESSION 7 and 8. Problem nº 3. Is the solution worse than the problem?	
Description	Students must watch the videos and complete the tasks assigned on the Edmodo platform.
Contents	Biotope, biocenosis and communities intra and interspecific relationships
Materials	Inter and intraspecific relationships
Activities	Online activity on Educaplay Ecology test review nº 3 on Edmodo

SESSION 9. The Mesocosm experience: discussion and conclusions	
Description	Students review the data they have collected during the experimental phase and revise and fill the report template
Contents	Ecology principles statistical graphs and correlation
Materials	Mesocosm report assessment; mesocosm report template
Activities	Upload the final reports on the platform

SESSION 10. Discussing the Problematic Situations	
Description	Students analyse the problems and decide which one they want to present. They review the concepts related to the topic.
Contents	Population ecology intra and interspecific relationships structure and components of an ecosystem, invasive species.
Materials	Assessment rubric for PBL
Activities	Self-assessment with the PBL rubric

SESSION 11. Scientific Symposium	
Description	Students design the visual material for the oral presentation.
Contents	Problem nº 1 Problem nº 2 Problem nº 3
Materials	Canva Prezi Genially
Activities	Self-assessment using the PBL oral presentation rubric

Table 5. Out-of-class lesson plan

SESSION 1. Introduction: overview of the Flipped Classroom approach	
Description	During this first session, it will be explained what the Flipped Classroom approach consists of. *Edmodo*, the online learning platform, will be presented, where students will find all the videos, activities and materials to carry out their tasks. In addition, five stable groups of four members will be created. Finally, the teacher will explain the problem situations according to the PBL, and the IBL named *The Mesocosm experience* that the students will have to perform, as well as the mathematics and statistics contents that will be worked on in class based on population ecology.
Timing	50 minutes
Aims	- To introduce FC approach - To get in touch with digital educational environments - To foster help among students
Contents	- LMS platform and digital learning - Ecology principles - The experimental model
Competences	CMST, CLC, CD, L2L
Methodology	In this first session, the class will be traditional: the teacher will explain the subject matter of the didactic unit and how it will be approached
Activities	**Activity 1 (10’).** Explanation of the FC: why we will use this approach and what it is expected to achieve. Creation of the stable groups. **Activity 2 (10’).** The teacher, with the help of the projector and computer, will show the various sections present in the *EdModo* platform, chosen as Learning Management System (henceforth, LMS). The teacher will send by e-mail the invitation to the students so that they can access the platform. **Activity 3 (15’).** Introduction to PBL: what a "problematic situation" is and how it can be solved: how to create hypotheses and follow the scientific method, presenting the problematic situations studied throughout the didactic unit. It will also be explained how and when the solutions will have to be uploaded to the virtual platform. Presentation of the assessment rubric to assess the problem-based activities and the oral presentation that will take place at the end of the didactic unit. **Activity 4. (15’).** A video about mesocosms will be shown to present the project that the students will have to carry out during the month. The mathematics content that will be used to complement the project will be presented. Explication of the materials (worksheets, notebook) and the report to be presented at the end of the didactic unit.

SESSION 2. The Mesocosm Experience begins	
Description	This session will take place in the laboratory, where students will find various elements (jars, seedlings, sand and soil) to investigate how to build a mesocosm and make it viable once it is hermetically sealed; students should decide as a group how to set up the experiment. Finally, they will begin to complete the notebook provided, which they will have to fill every day before classes begin.

Timing	50 minutes
Aims	- To plan an experimental design of a mesocosm. - To perform effective internet searches. - To strengthen group work
Contents	- Environmental factors - Biotic and abiotic factors.
Competences	CMST L2L SIE DC
Methodology	This session will take place in the laboratory; the groups work autonomously, following the different worksheets and notebooks at their disposal
Activities	**Activity 1 (50').** The teacher will guide the groups by asking questions such as "*What kind of plants do you choose? Do they need a lot of light or rather shadow*?, namely to oversee the process and to stimulate the investigation.
SESSION 3 and 4. Problem nº 1. What is an ecosystem and how does it work?	
Description	During these two sessions, the groups will research critical ecosystems and apply statistical methods to assess the state of danger of these environments, answering the two proposed questions.
Timing	50 minutes
Aims	- To understand the factors that make up an ecosystem - To create dialogue and search for solutions - To research, identify and select scientific information.
Contents	- Structure and components of an ecosystem - Productivity and energy flux - Climate change
Competences	CMST DC SIE SCC CAE L2L CLC
Methodology	In class, working in groups, they will have to follow the guidelines to complete the task. Students will be allowed to work using their smartphones and one tablet per group both to do research as well as to work on the virtual platform to review videos and resources. Once the task is completed, a group leader will upload the completed worksheet to the virtual platform.
Activities	**Activity 1 (50').** The teacher will use questions such as *"Can you tell me an ecosystem you have visited during a trip? What animals or plants have you seen?"* to review communicative expression and scientific concepts. The teacher will review progress, answer questions and check that all group members are working properly.
SESSION 5 and 6. Problem nº 2. The threat of invasive species	
Description	During these two sessions, the groups will work on the problem of invasive species, focusing on the Mediterranean basin and answer the four questions.
Timing	50 minutes
Aims	- To understand the importance of these ecosystems

	- To reinforce the ability to search for and analyse sources of information - To represent data through statistical tables.
Contents	- Population ecology - Reproduction and mortality rate of a population - Invasive species
Competences	CMST DC SIE SCC CAE L2L CLC
Methodology	In class, working in groups, they will have to follow the guidelines to complete the task. In class, the groups will be allowed to work using their smartphones and one tablet per group both to do research as well as to work on the virtual platform, to review videos and resources. In general, the groups will have a maximum of 5 days to upload the worksheet on the virtual platform. Once the task is completed, a group leader will upload the worksheet to the virtual platform.
Activities	**Activity 1 (50').** The teacher will ask questions such as *"Have you ever heard about the water hyacinth? It is an invasive species, could you look it up and see if it is present near Valencia"*, as a strategy to check the accuracy of the groups' research, whether students are following the guidelines and the bibliographical sources provided. Then, the teacher will review progress, answer questions and check that all group members have been assigned their tasks.

SESSION 7 and 8. Problem nº 3. Is the solution worse than the problem?	
Description	This session will work on the concept of biocenosis, biotope and community and the inter-species relationships of prey-predator by analyzing a problematic situation that affects Australia since the 19th century, when the rabbit was introduced and is now a very dangerous plague. The students must investigate whether it is viable to release a species of owl trained to hunt rabbits.
Timing	50 minutes
Aims	- To interpret the depredator-prey relationship - To build an ecological food web - To manage targeted research about the animals and their habitats - To work in group
Contents	- Food webs and food chains - Intra and interspecific relationships - Ecosystem
Competences	CMST DC SIE SCC CAE L2L CLC
Methodology	In class, working in groups, they will have to follow the guidelines to complete the task. In class, the groups will be allowed to work using their smartphones and one tablet per group both to do research as well as to work on the virtual platform to review videos and resources. In general, the groups will have a maximum of 5 days to upload the worksheet on the virtual platform. Once the task is completed, a group leader will upload the completed worksheet on the virtual platform.
Activities	**Activity 1 (50').** The teacher will deliver the worksheet for the problem nº 3. The teacher will ask questions using the following verb forms: *"in*

	your opinion, ...? why? What would you do?" to check the correct use of the answer forms and students' ideas. The teacher will review progress, answer questions and stimulate the debate among the group members, imitating a real research group.

SESSION 9. The Mesocosm experience: discussion and conclusions

Description	In this session, the mesocosms and the first results of the experiment will be presented for a general review of the didactic unit. Students will discuss their experiments and connect this knowledge to the theoretical background, with the teacher's help.
Timing	50 minutes
Aims	- To strengthen observation and analytical skills - To interpret variables - To strengthen reading comprehension and oral expression
Contents	- Ecosystem - Biotic and abiotic factors - Energy flux - Statistical graphs and correlation
Competences	CMST DC SIE SCC CAE L2L CLC
Methodology	In this session, students will work partly individually, filling in a questionnaire and then collectively to draw the conclusions of the didactic unit.
Activities	**Activity 1 (10').** The teacher will provide a questionnaire with questions about the experiment. **Activity 1 (40').** The teacher will ask the class to discuss the questionnaire and interpret the data collected during the experiment: temperature, changes in the water, presence of insects and how to include the data in the final report. The teacher will pose questions like *"How did the temperature affect the experiment?" "How did the insects appear?"*

SESSION 10. Discussing the Problematic Situations

Description	In this session, each group will focus on preparing the oral presentation and revising the concepts related to the problems seen throughout the course. Each group will choose one problem out of the three analysed in order to focus on studying the related contents of the didactic unit.
Timing	50 minutes
Aims	- To interpret data - To strength the ability to synthesize - To improve written and oral skills
Contents	- Invasive species - Intra- and interspecific relationships - Population ecology - Structure and components of an ecosystem

	- Food webs and food chains
Competences	DC CLC CAE SCC SIE
Methodology	The class will work in groups: each group will have a tablet to review all the material related to the problems and the internet to choose which platform to use for the visual support. The groups will have the assessment rubric at their disposal to know how to prepare both the presentation and the visual support adequately.
Activities	**Activity 1 (30').** The teacher will assist the groups to clarify the concepts that the group has decided to defend in the oral presentation: a review of the material and problems, theoretical concepts, how to prepare the script of the oral presentation. **Activity 3 (20').** The teacher will illustrate the web applications (Canva, Genially and Prezi) that the groups can use to prepare the final presentation or poster as visual support for the oral presentation.

SESSION 11. The Scientific Symposium	
Description	This didactic unit is designed as a series of presentations of the groups to the audience.
Timing	50 minutes
Aims	- To practise the oral expression - To strengthen group collaboration
Contents	- Population ecology - Ecology threats - Environmental factors - Intra and inter-relationships.
Competences	CMST DC SIE SCC CAE L2L CLC
Methodology	Each group will have the projector and the class computer at its disposal. Each group will have between 8 and 10 minutes to make the presentation.
Activities	**Activity 1 (40').** The teacher introduces each group and will control the time of presentation, oral expression, and contents. **Activity 2 (10').** The teacher will analyse the presentation with each group using the evaluation rubric.

SESSION 12. Final exam	
Description	The exam consists of eight questions: the first two are more demanding because they are open-ended and, therefore, worth two points each. The other six are multiple choice and true/false questions and are worth one point, for a total of ten points.
Timing	50 minutes
Aims	- To check reading comprehension - To check content retention - To check analytical skills
Contents	- Environmental factors: biotic and abiotic factors

	- Population dynamics - Intra and inter relationships - Biocenosis and community - Structure and components of an ecosystem
Competences	CMST SCC CAE CLC
Methodology	The exam is individual. Wrong answers do not count. This mark will then be weighted on average (10%) with the rest of the activities. A simple test has been preferred because of the complexity of the didactic unit. The aim is to check individual understanding.
Activities	**Activity 1 (50').** The teacher will deliver the exam. The activity is individual, but the teacher will be available to help the students to understand the questions.

Table 6. In-class lesson plan

3.10 Reinforcement tasks

Reinforcement activities (ANNEX VI) will be assigned to be done at home and are focused on reinforcing the main concepts. These tasks include the completion of short questionnaires immediately after viewing the video as well as creating scientific glossaries to be included in each student's portfolio. Other specific vocabulary activities, linking concepts and answering true/false questions are also present. The combination of different activities is adapted to the learning pace of each student. Some tasks are hosted on the Edmodo platform, such as questionnaires and editable word documents. The questionnaires have an automatic feedback system in which the platform records the answers so that the teacher can quickly see the results; the word documents can be edited directly from the computer or tablet and delivered virtually to the teacher. Finally, the rest of the activities are hosted online on the Educaplay and Quizizz platforms. In these cases, students enter with their school email address so that the teacher can record the process, view the results and include them in the student's portfolio. Moreover, through the Edmodo platform, the teacher can assign the tasks with a time limit to ensure that the students watch the videos and complete the tasks at a convenient time and keep up with the progress of the didactic unit.

3.11 Extension tasks

There are more difficult activities in the didactic unit for students who have already achieved their learning and are able and willing to continue their research. These activities are entirely voluntary, as they require effort in both text comprehension and written expression. In addition, some of them make special reference to statistical content. Each completed activity counts for one extra point that will be added to the student's final mark. They can only be achieved if the reinforcement activities have also been fulfilled. Students can decide to share their findings openly on the platform with the rest of the classmates or to present it individually to the teacher. (ANNEX VII)

3.12 Assessment and evaluation

In a dual context such as CLIL, it is necessary to assess not only content but also language skills. Assessment is critical because it allows us to reflect on the results achieved and to be able to evaluate the whole teaching-learning process. In a complex context such as the one presented in this MD, special emphasis will be placed on formative assessment, which aims to consider the student's learning process and analyse their strengths and weaknesses in order to plan future educational actions better.

Therefore, students will have at their disposal specific rubrics (ANNEX VIII) to assess all the different activities: the laboratory project, the problem-solving procedures, oral presentations and group work, as well as a more general rubric taking into account the following assessment criteria, which will be presented at the beginning of the didactic unit. The evaluation rubric sets out the specific tools applied to collect and evaluate the information based on the assessable learning standards. The following instruments will be used:

- Direct observation of class work
    - Attendance, interest, and participation
    - Classroom and laboratory behaviour
    - Language, clarity of vocabulary
- Out-of-class tasks
    - Activities delivered on the Edmodo platform

- Online tests
- Extension tasks

➢ Productions

- Notebooks and reports
- Elaboration of digital material
- Oral presentations

➢ Exam

Moreover, the ICT tool *Idoceo* will be used as a digital tool to unify the evaluation criteria in a single space. There, all the information collected with all the instruments will be reflected. With the help of this application, it will be possible to calculate the final mark.

Figure 5. Idoceo sample

https://www.idoceo.net/

When it comes to numerical grading and measuring the results achieved by each student, it will be considered applying the following ranges as follow:

QUALIFICATION CRITERIA	FINAL MARK
Direct observation	40%
Out-of-class tasks	20%
Productions	30%
Exam	10%

Table 7. Percentage weighting of the final grade

4 CONCLUSIONS

STEM Education today represents an essential part of our students' learning process, with a clear interdisciplinary focus that aims to promote the integration of different scientific disciplines, namely Science, Technology, Engineering and Mathematics. Due to its nature, the STEM approach is highly practice-oriented and concentrated on working with problems related to the real world, applying theoretical knowledge to solve them. Creating a stimulating learning environment thus becomes a challenge for the teacher, who must not only ensure that students learn effectively but also set tasks that interest and engage them.

In these circumstances, in this MD, I have proposed a didactic unit that not only integrates the principles of the Flipped Classroom but also aims to work in a CLIL environment, with the intention to address two types of problems in the education system, science learning and language learning. In order to provide an effective solution to the first problem, this didactic proposal offers a practical approach to science teaching, integrating two scientific disciplines in such a way that the contents intertwine and support the understanding of both subjects, Biology and Maths. Secondly, working through PBL and IBL encourages an interest in science and an awareness of the ecological phenomena that surround us currently. In the same token, the target language, English, is not only the vehicle for learning but also the object of learning: students at home learn in English through short videos with an additional text and an integrated online dictionary. Once in the classroom, students work in groups, discuss, complete tasks, solve problems, and actively use the language while processing the scientific content. Moreover, learning the target language is favoured by the dynamic and creative context given the conditions of cooperative learning, based on communication between classmates and the teacher during the whole hour of class practice. Finally, technological tools favours meaningful learning since they are a support that is always available at home and allows learning new vocabulary thanks to the videos and the possibility of watching them infinite times.

The structure of the didactic unit has been designed bearing in mind all the components in order to achieve adequate learning for students: the videos and self-correction tasks focus on vocabulary enhancement. In contrast, group work focuses on understanding the biological phenomena around us. Consequently, the didactic objectives, such as knowing how to describe the structure and components of an ecosystem, identifying real problems and proposing solutions, knowing how to communicate with classmates, are fully accomplished.

In conclusion, the combination of two methodologies, FC and CLIL, may prove to be the ideal environment to foster deep learning, increase the autonomy of our students, encourage active learning through innovative methodologies that foresee using the classroom as a space for cooperation and where the teacher becomes a facilitator, putting the students at the centre of their own learning processes.

Based on the above, it is possible to conclude that the use of pedagogical procedures such as Problem-Based Learning and Inquiry-Based Learning among the student-centred methodologies, coupled with the FC methodology in a CLIL environment, improves our students' science learning as well as their language skills.

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LEGAL FRAMEWORK

Law 4/2018, of 21 February, which regulates and promotes multilingualism in the Valencian education system.

http://dogv.gva.es/portal/ficha_disposicion.jsp?L=1&sig=001885%2F2018

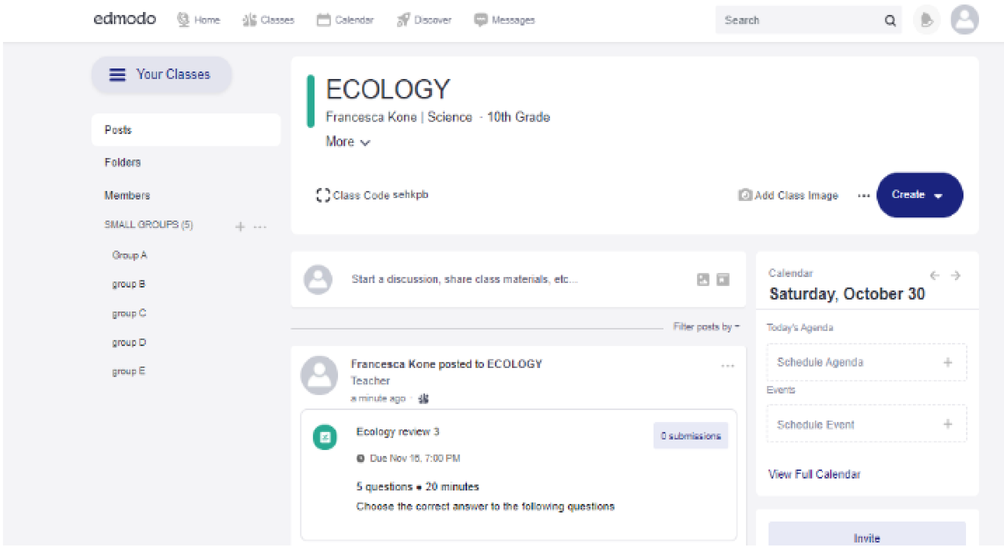
Decree 87/2015, 05/06/15, of the Valencian Government, establishing the curriculum and developing the general regulation for Obligatory Secondary Education in the Valencian Community (DOGV 10.06.2015). https://goo.gl/rHLka6

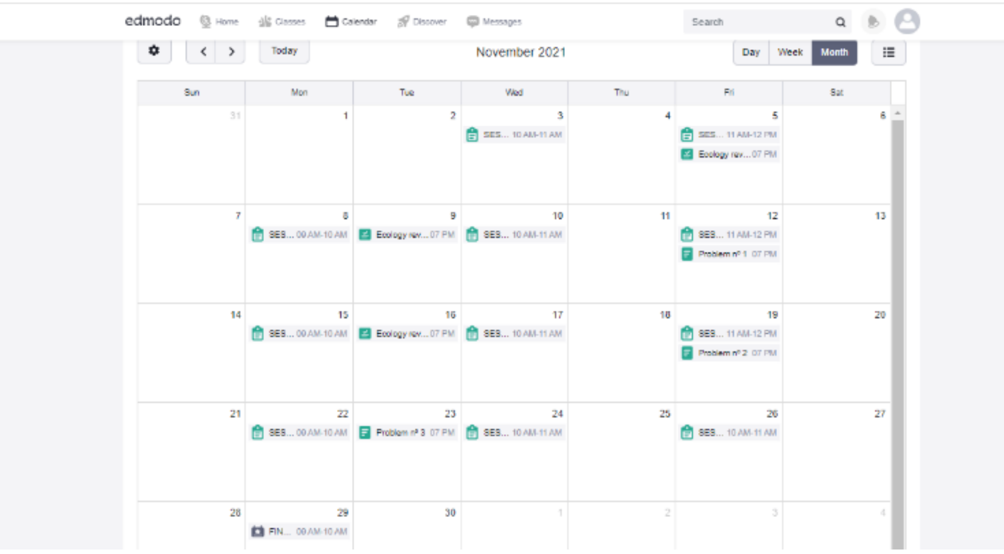
Decree 136/2015, 04/09/15, of the Valencian Government, modifying Decree 128/2014, establishing the curriculum and developing the general regulation for Primary Education and Obligatory Secondary Education and Baccalaureate in the Valencian Community (DOGV 09.09.2015). https://goo.gl/jq9riN

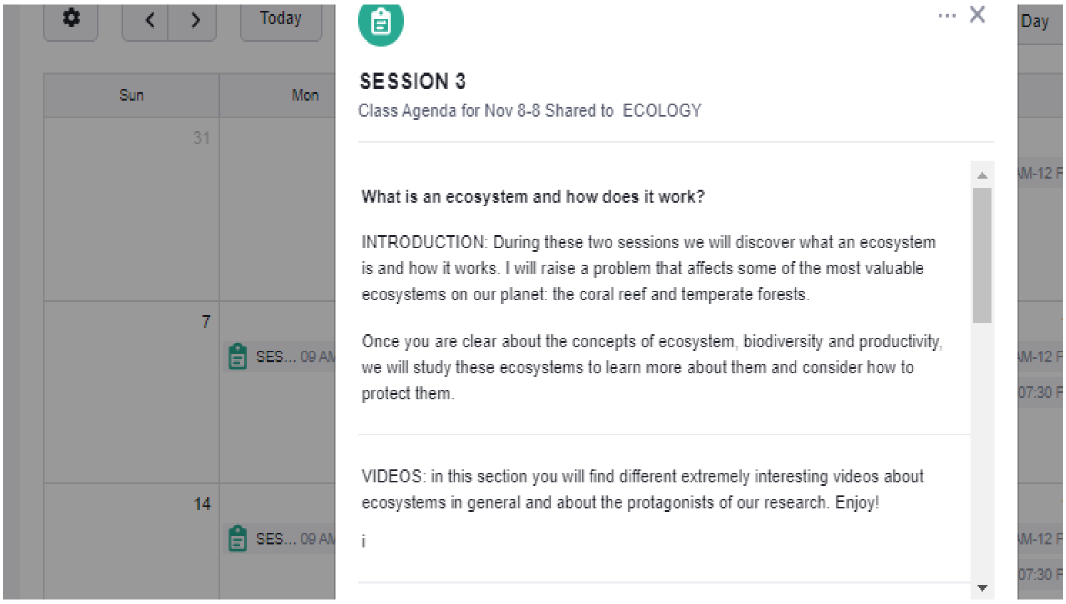
6 ANNEXES

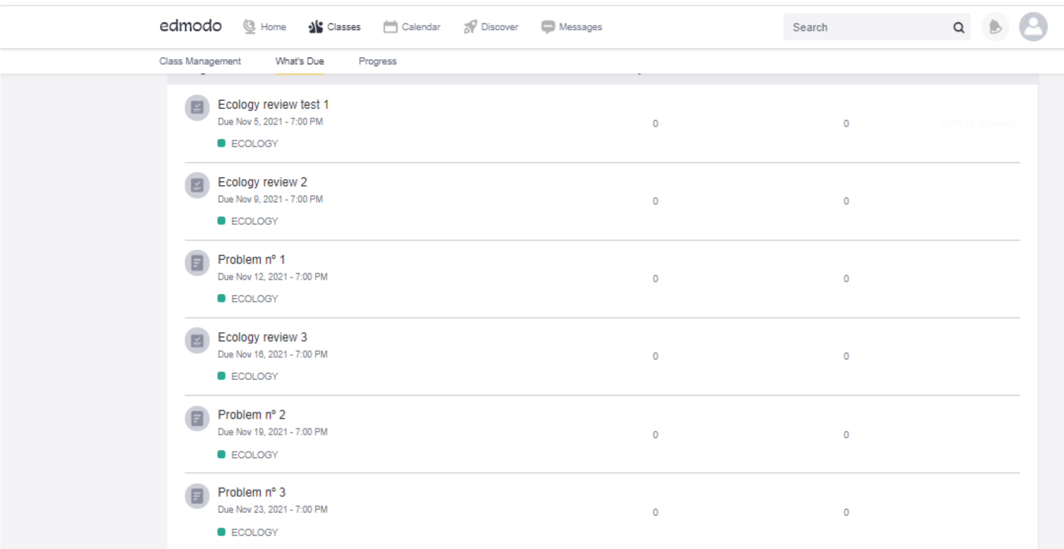
6.1 ANNEX I

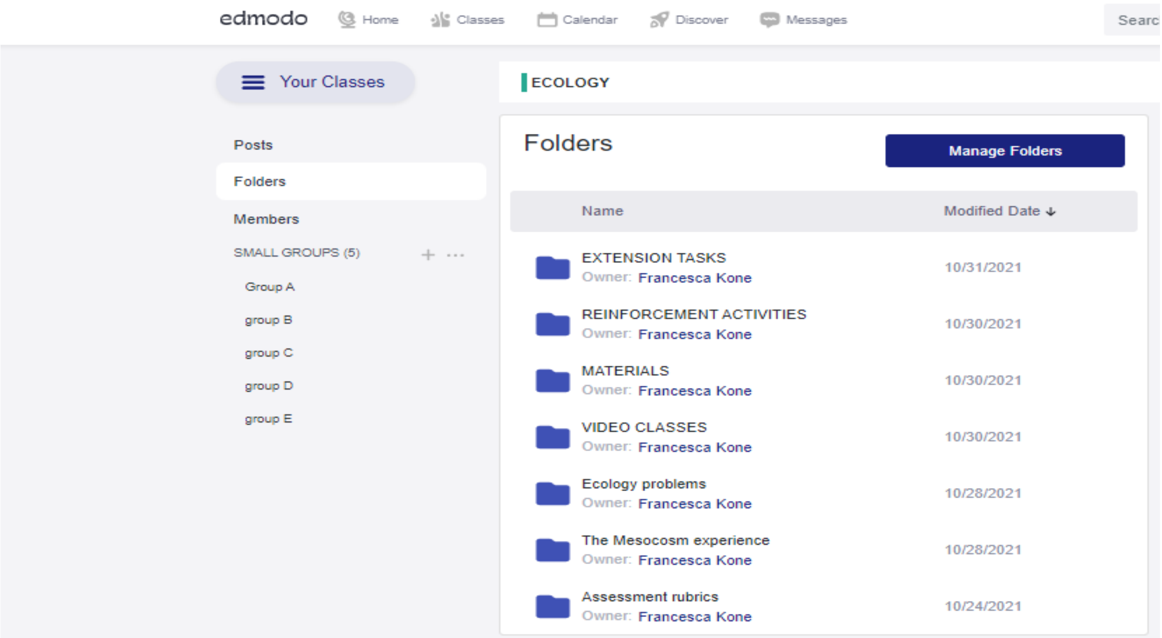
Edmodo platform organization






Today
Sun
Mon
Day
SESSION 3
Class Agenda for Nov 8-8 Shared to ECOLOGY
What is an ecosystem and how does it work?
INTRODUCTION: During these two sessions we will discover what an ecosystem is and how it works. I will raise a problem that affects some of the most valuable ecosystems on our planet: the coral reef and temperate forests.
Once you are clear about the concepts of ecosystem, biodiversity and productivity, we will study these ecosystems to learn more about them and consider how to protect them.
VIDEOS: in this section you will find different extremely interesting videos about ecosystems in general and about the protagonists of our research. Enjoy!


edmodo
Home
Classes
Calendar
Discover
Messages
Search
Class Management
What's Due
Progress
Ecology review test 1
Due Nov 5, 2021 - 7:00 PM
ECOLOGY
Ecology review 2
Due Nov 9, 2021 - 7:00 PM
ECOLOGY
Problem nº 1
Due Nov 12, 2021 - 7:00 PM
ECOLOGY
Ecology review 3
Due Nov 16, 2021 - 7:00 PM
ECOLOGY
Problem nº 2
Due Nov 19, 2021 - 7:00 PM
ECOLOGY
Problem nº 3
Due Nov 23, 2021 - 7:00 PM
ECOLOGY



Folder MATERIALS: resources to conduct PBL research

https://schmidtocean.org/cruise-log-post/ocean-drivers-of-reef-productivity/

http://www.eolss.net/sample-chapters/c01/e6-18-06-04.pdf

https://www.frontiersin.org/articles/10.3389/fmars.2015.00113/full

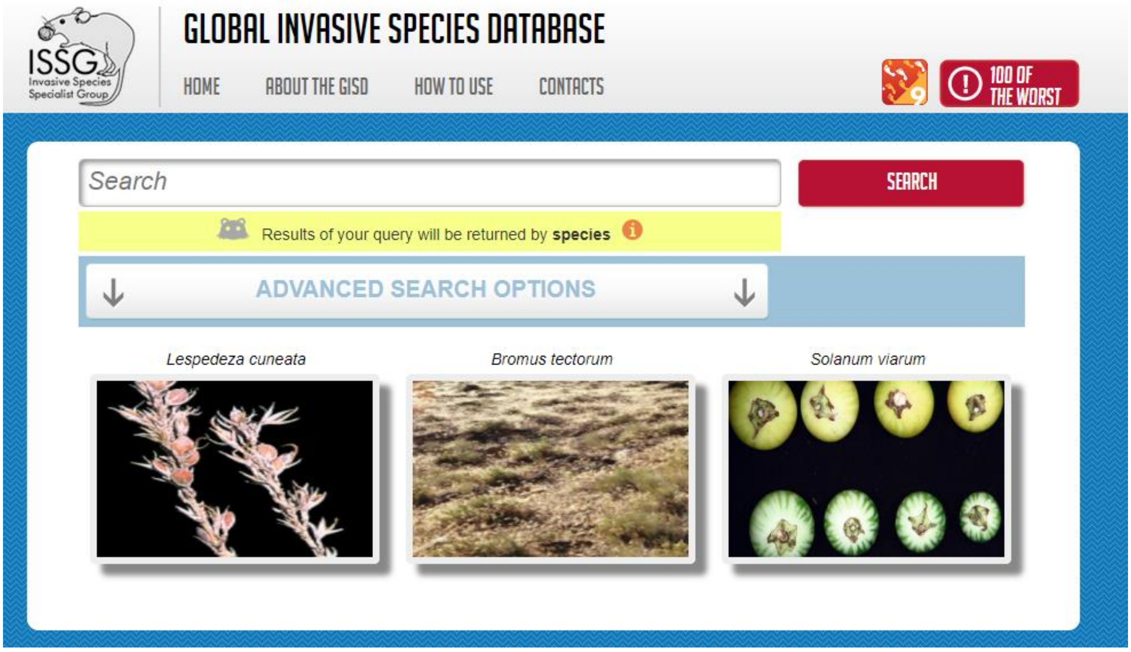
https://www.researchgate.net/publication/227606967_The_global_relationship_between_forest_productivity_and_biomass

https://www.ducksters.com/science/ecosystems/temperate_forest_biome.php

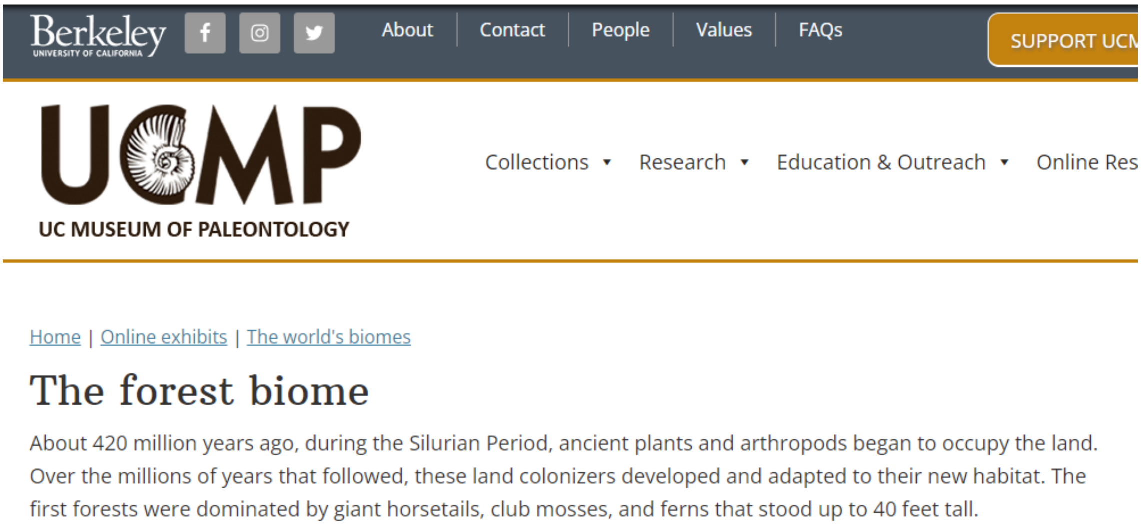
https://sciencing.com/forest-ecosystem-classification-31825.html

https://ucmp.berkeley.edu/exhibits/biomes/forests.php

http://www.iucngisd.org/gisd/



http://www.iucngisd.org/gisd/



https://www.berkeley.edu/

6.2 ANNEX II

Videos uploaded on Multidict.net

The Scientific Method

Ecology: terminology

What is an ecosystem

How to build a mesocosm

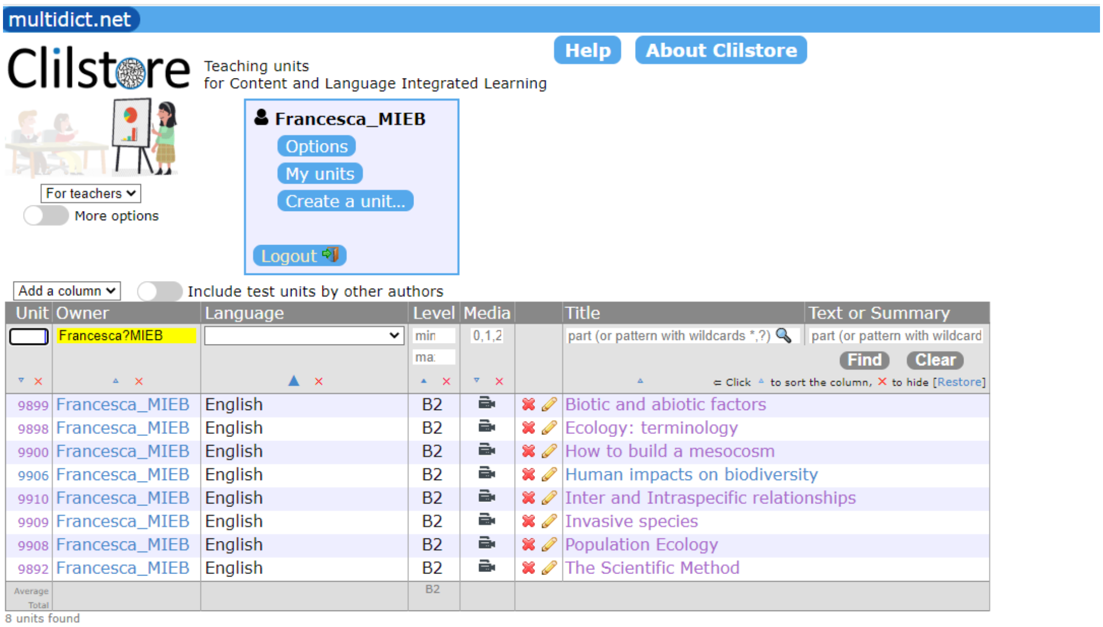
Biotic and abiotic factors

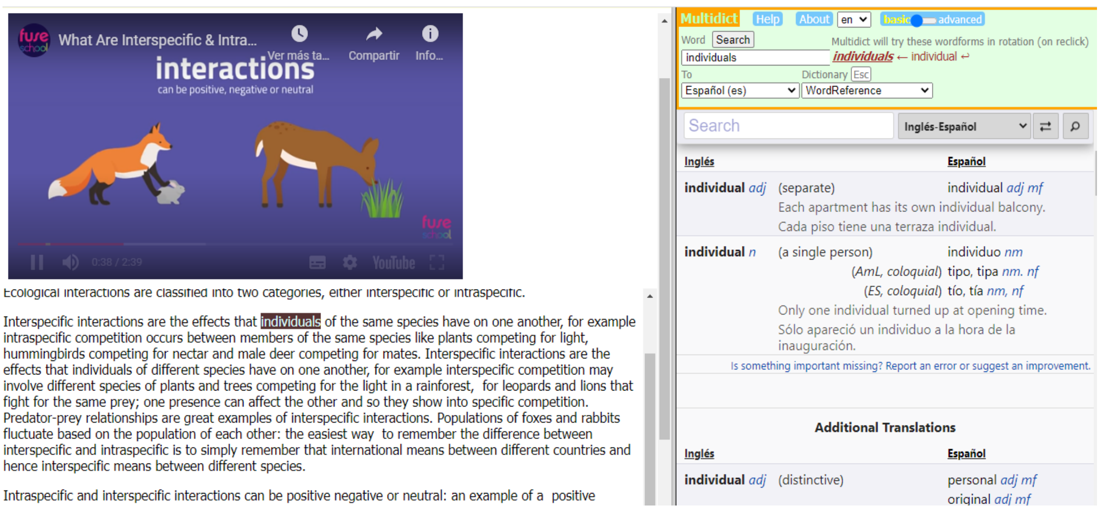
Human impacts on biodiversity

Population ecology

Inter and intraspecific relationships

Invasive species





6.3 ANNEX III.

Problem-based Learning materials and assessments.

PROBLEM 1

What is an ecosystem and how does it work?

Instructions: Groups A, C and E will work on coral reefs, groups B and D will work on the temperate forest. You have this guide to plan how to work and on the platform, you have many links and material.

The questions you must answer are:

How does light affect the productivity of the ecosystem in question? Design a graph.

Given the threats due to global change, what possible measures need to be taken?

Guidelines [1]

STEP 1. Explain the scientific concepts that you need to consider defining the problem by doing a literature search.

STEP 2. Narrow down the conditions of the situation to be investigated: look for the biological and ecological characteristics

STEP 3. Think and formulate hypotheses.

STEP 4. Indicate the experiment or investigation and what you would do, doing a new literature search. Explain if there are ways to solve it or if it is like other problems.

STEP 5. Prepare an outline or a drawing, giving the data obtained from your investigation.

PROBLEM 2

The threat of invasive species

To work on this session, you have many links to read on the platform.

Each group will choose an invasive species, animal or plant, now present in the Iberian Peninsula and will have to answer the following questions:

Where does it come from?

Which local species does it compete with?

What economic problems does it create, for example to agricultural or fishing activities?

What possible measures have been adopted? How can they be improved?

Guidelines [1]

STEP 1. Explain the scientific concepts that you need to consider defining the problem by doing a literature search.

STEP 2. Narrow down the conditions of the situation to be investigated: look for the biological and ecological characteristics.

STEP 3. Think and formulate hypotheses.

STEP 4. Indicate the experiment or investigation and what you would do, doing a new literature search. Explain if there are ways to solve it or if it is like other problems

STEP 5. Prepare an outline or a drawing, giving the data obtained from your investigation.

PROBLEM 3

Is the solution worse than the problem?

The rabbit, introduced in Australia in the late 19th century and with no natural competitors, is now a real plague. The Australian Government has asked your research group to study possible measures to tackle the problem. One of the proposals is to introduce an owl trained to hunt rabbits.

Both the government and environmental groups are asking you what could happen to the rabbit population and if this could be a viable measure that can solve the problem.

To solve the problem, your group must:

Design the inter-specific relationships of the Australian ecosystem where the rabbit now lives.

Design possible food webs of the Australian ecosystem after the introduction of the owl: will it hunt only rabbits, or will it find other species more palatable?

Guidelines [1]

STEP 1. Explain the scientific concepts that you need to consider defining the problem by doing a literature search.

STEP 2. Narrow down the conditions of the situation to be investigated: look for the biological and ecological characteristics.

STEP 3. Think and formulate hypotheses.

STEP 4. Indicate the experiment or investigation and what you would do, doing a new literature search. Explain if there are ways to solve it or if it is similar to other problems.

STEP 5. Prepare an outline or a drawing, giving the data obtained from your investigation.

6.4 ANNEX IV

THE MESOCOSM EXPERIENCE

GENERAL WORKSHEET

Instructions

Before the experiment

Read the characteristics of each plant carefully and decide with your group which ones you want to insert in the jar. In the notebook, draw the first hypotheses following these questions: *Will the plants survive? Will they both die or only one? What factors will be most important for their survival?* Check in the notebook the variables to be monitored each day and add others of your interest, if needed.

During the experiment (one month long)

Make daily notes of the variables under examination and write them down in your notebook. Take photos to complete the experiment and make extra notes if you notice anything particularly interesting.

After the experiment

Your teacher will ask you to analyse the data obtained from the observations and compare them with your initial hypotheses. You will write a detailed report about the experiment.

General information about the plants.

Adiantum raddianum fragantissimum

Adiantum is a perennial plant, belonging to the fern group. It is a very popular herbaceous plant grown indoors. It is known as *Venus hair*. It is a plant of tropical origin, from countries such as Uruguay, Brazil and Paraguay. It prefers a light shady location but can tolerate partial shade with filtered sun. It prefers loose and fertile soil rich in organic matter, which keeps humidity but with good drainage. *Adiantum* needs regular watering, moist but not waterlogged soil. Substrate is rich in organic matter.

Fittonia verschaffeltii

Fittonia verschaffeltii is a creeping houseplant. It is characterised by its small size. Fittonia is a heat-resistant plant but not cold-resistant. Below 15°C the plant tends to lose its leaves. Although it can withstand well in poorly lit areas, it is best to place it in a well-lit place, avoiding at all times that the sun's rays fall on the plant as they would burn it. *Fittonia* needs frequent watering, preventing the substrate from drying out. In addition, it is necessary that the humidity of the environment is high.

Petroselinum crispum

Commonly known as parsley, *Petroselinum* is a Mediterranean plant that needs sun or semi-shade but should not be exposed to direct sunlight for more than 4 to 6 hours a day. This plant requires a humid environment, especially in its early stages. For this reason, Petroselinum should be watered so that the soil is always moist.

Origanum vulgare

Origanum, commonly known as oregano, is a perennial herbaceous plant, native of the Mediterranean area. To grow at its best, it must thrive in sun and warmth, but can live in semi-shade exposure and mild temperatures. It prefers dry or not very well-watered soils, although it adapts to any type of soil.

THE MESOCOSM EXPERIENCE

RECORDING OF DATA AND OBSERVATIONS

Day 1: our hypothesis.

VARIABLES	date	date	date	date	date	date	date	date	date
Environmental temperature									
Condensation YES									
Condensation NO									
Animals appear									
Animals disappear									
Mould yes									
Mould no									

EXTRA OBSERVATIONS

PICTURES (Past here your pictures with the date)

THE MESOCOSM EXPERIENCE

THE LAB STEPS

MATERIALS

For each mesocosm (one per group):

One 5-litre glass jar

Peat 250 gr

Gravel 500gr

Two types of plants of your election

Water 60 gr

METHODOLOGY

Arrange the sand and soil in layers at the bottom of the jar.

Place two of the plants with the roots sufficiently anchored in the soil.

Add water.

Seal tightly and place the jar in controlled environmental conditions where it will remain for a month.

THE MESOCOSM EXPERIENCE

THE FINAL REPORT

INTRODUCTION

The abiotic and biotic factors are…

METHODS

In our experiment, we tested…

RESULTS

After one month, we observed…

DISCUSSION

The data evidenced…

CONCLUSIONS

We can conclude that…

THE MESOCOSM EXPERIENCE

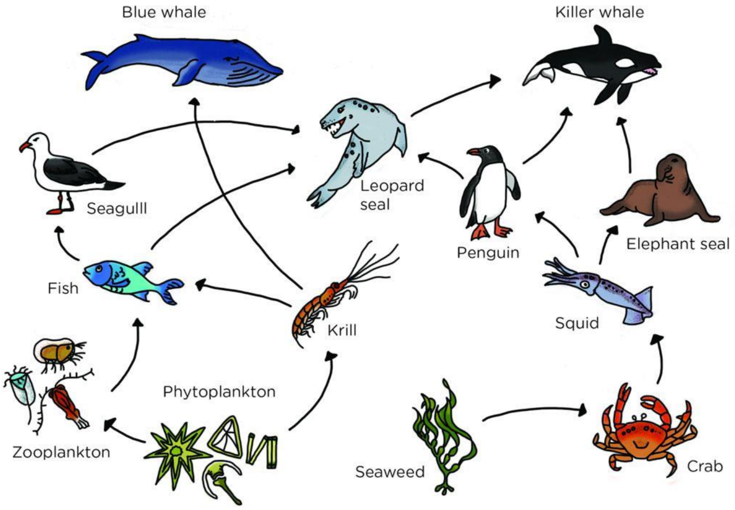
THE QUESTIONNAIRE

Analysing the results of your mesocosm, what is the variable that most interested you and why? Which of the variables for you has had the greatest impact on the development of the experiment and why? In your opinion, what could happen by having the jar sealed for the next three months? And twelve months?

6.5 ANNEX V

ECOLOGY: FINAL EXAM

1. From this trophic web, extract at least two food webs (2 points)



____

____

2. Explain the difference between ecological niche and habitat (2 points)

____

____

____

CIRCLE THE CORRECT ANSWER

3. A set of individuals capable of reproducing and generating fertile offspring and living in a given time and space. (1 point)

   A) Community

   B) Biotope

   C) Population

   D) Biocenosis

4. Abiotic factors are (1 point)

   A) light, temperature, plants, water, air.

   B) temperature, water, animals and gases

C) light, temperature, water, animals, plants.

D) light, water, temperature, soil, atmospheric gases

5. In ecology, which level of organisation does the image represent? (1 point)

A) Community

B) Organism

C) Population

D) Ecosystem

E) Biosphere

6. The area of uniform environmental conditions that provides living space for an assemblage of flora and fauna (1 point)

A) Biotic Factor

B) Biotope

C) Biocenosis

D) Ecosystem

TRUE/FALSE QUESTIONS

7. Autotrophs produce their own food (1 point)

A) False

B) True

8. Plants belong to the kingdom Plantae (1 point)

A) False

B) True

6.6 ANNEX VI

Reinforcement activities

Terminology: reinforcement activity

Directions: Read each definition and write the correct word on the line.

organisms _ vast _ variation _ species _ affect _ habitats_ niche_ mutualism_

1. Where things (usually animals) live
2. A lot of area
3. Specific types of animals.
4. Interaction between individuals of different species that results in positive effects
5. Living creatures
6. The role an organism plays in a community
7. The differences between individuals within a species

Habitats and niches: reinforcement activity

Write the letter and the number that matches in each box.

	HABITATS
1	They live in tropical and subtropical forests in Central Africa
2	They live in almost all oceans of the world.
3	They live in a terrestrial habitat but near wet areas, sheltering under leaf litter and fallen tree trunks or stones.
4	They live in tropical areas of America, Australia, Africa, and Asia, especially in freshwater areas such as rivers, lakes and wetlands.
5	They live in areas where vegetation is abundant, and the tropics are the areas where the greatest number of species are found.

	NICHES
A	As juveniles, they feed on molluscs, frogs, snakes, and lizards. As adults, they eat fish but are capable of hunting antelopes, zebras, and other animals.
B	Their diet is based on small crustaceans, spiders, snails and worms.
C	It feeds on leaves, stems, fruits, bark and shoots, and occasionally on small invertebrates such as ants, worms, termites, and other small animals.
D	It can eat any food that dissolves in water, preferring nectar and tree sap, but some species feed on decomposing fruit.
E	They feed on plankton and tiny fishes

ORGANISM	NAME	HABITAT	NICHE
			
			
			
			

Food Chains: reinforcement activity

Assign each definition its respective appropriate term

1. Consumer that eats only consumers	A. Organism
2. Any living things	B. Ecosystem
3. An animal that hunts another animal	C. Herbivore
4. Consumer that eats both consumers and producers	D. Carnivore
5. A place where living and non-living things are	E. Omnivore
6. An animal that is hunted by another animal	F. Predator
7. Consumer that eats only producers	G. Prey

Give an example of each of the following:

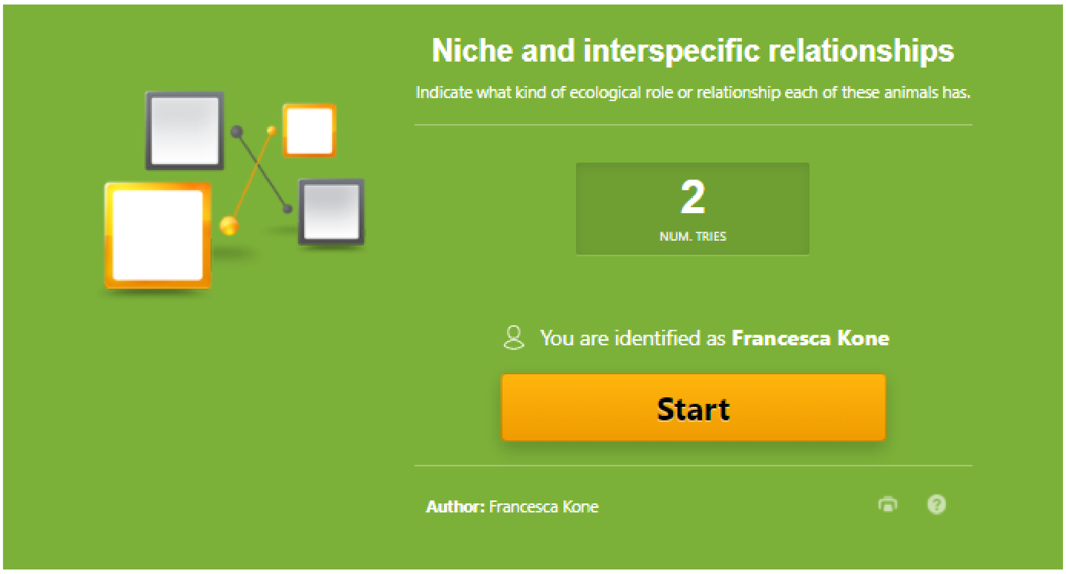
1. Herbivore
2. Carnivore
3. Omnivore

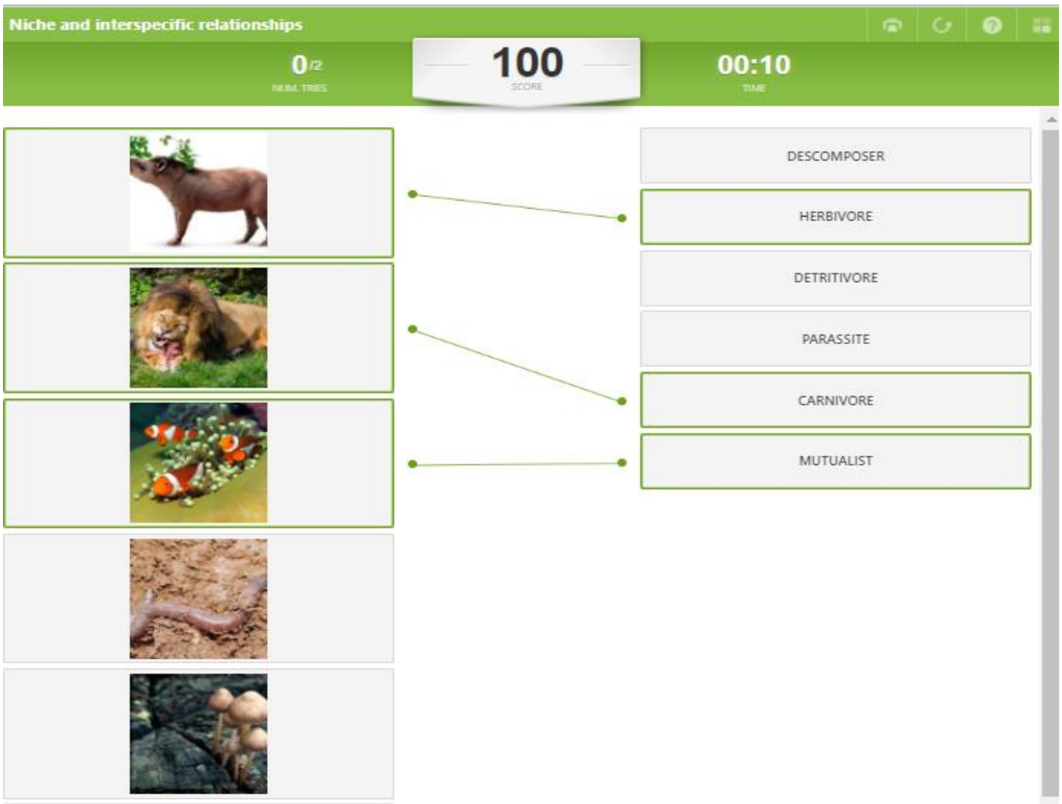
Create a food chain using these organisms:

Sun   Caterpillar   Bird   Earthworms   Grass

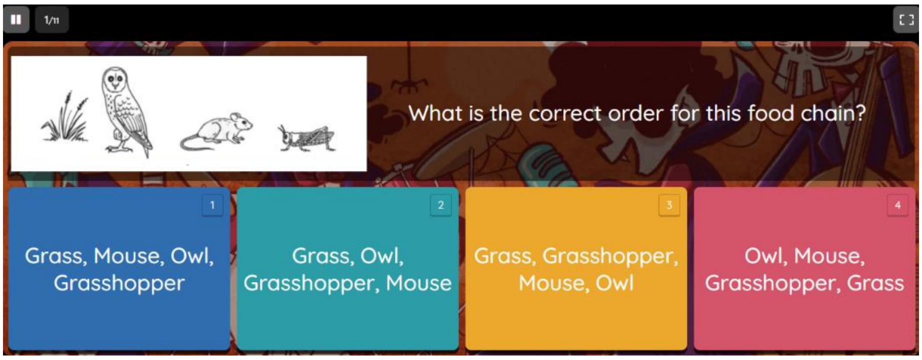
______→____→____→____→

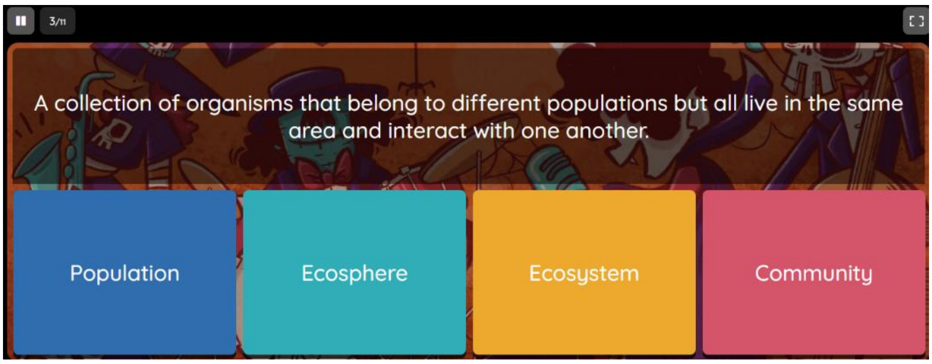
Educaplay reinforcement activity


Niche and interspecific relationships
Indicate what kind of ecological role or relationship each of these animals has.
2
NUM. TRIES
You are identified as Francesca Kone
Start
Author: Francesca Kone

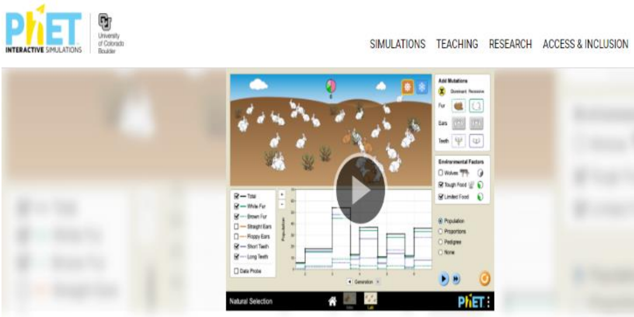

Niche and interspecific relationships
0/2
100
00:10
DESCOMPOSER
HERBIVORE
DETRITIVORE
PARASSITE
CARNIVORE
MUTUALIST

[Quizizz reinforcement activity]

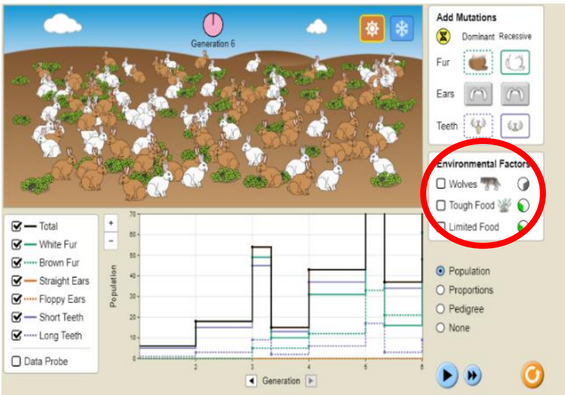


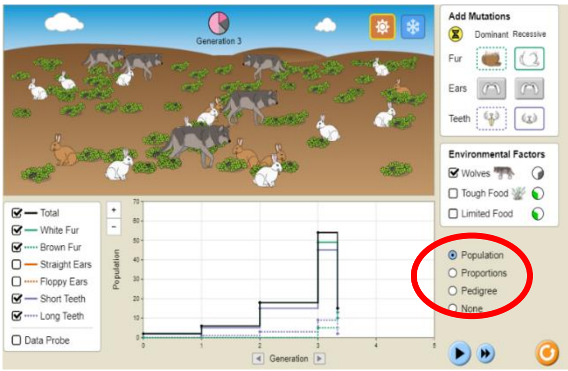


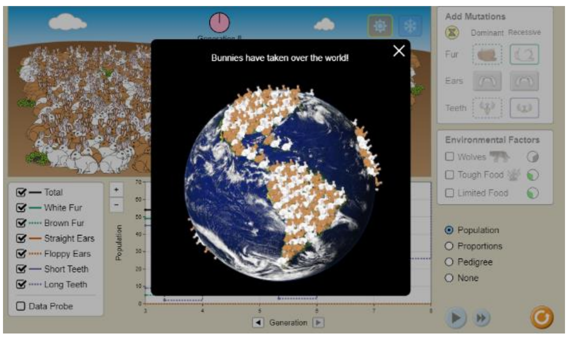
[Phet University Colorado Simulation Game]



Natural Selection







Edmodo questionnaire nº 1.

Question 1
1 point

Previous Next

What is a population?

- A. Set of individuals of the same species living together in a given territory and relating to each other.
- B. Set of species that coexist in a given territory and are mutually related.
- C. Set of individuals that live together in a given territory and are mutually related.
- D. Set of individuals of the same community living together in a given territory and relating to each other.

Question 2
1 point

Previous Next

Which of the following is not essential in an ecosystem?

- A. Relationship between biocenosis and biotope
- B. All others are necessary
- C. Abiotic components
- D. Community of living things

Edmodo questionnaire nº2

Question 1
1 point

Previous Next

Why are many of the Earth´s ecosystems threatened?

- A. Because the climate change
- B. Because the man is changing them
- C. Because there is not more place for living

Question 2
1 point

Previous Next

Where does the energy of most of the ecosystems come from?

- A. Sun
- B. Bacteria
- C. Electricity
- D. Air

Question 3
1 point

Previous Next

The place where organisms live is .....

- A. the ground
- B. the habitat
- C. the sea
- D. the foodweb

Edmodo questionnaire nº 3

Question 1
1 point

Previous Next

What are the two main parts of an ecosystem?

- A. Animals and plants
- B. Biotic & abiotic
- C. Habitat and rocks
- D. living and non living things

Question 2
1 point

Previous Next

Temperature, light, air, water, and soil are all _____ parts of the environment

- A. alive
- B. biotic
- C. abiotic
- D. living

Question 3
1 point

Previous Next

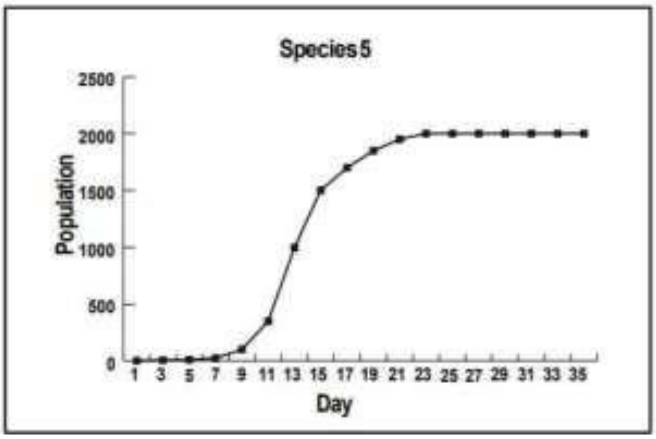
A relationship between two organisms in which one organism benefits and the other is unharmed...

- A. Mutualism
- B. competition
- C. Parassitsm
- D. Commensalism

6.7 ANNEX VII

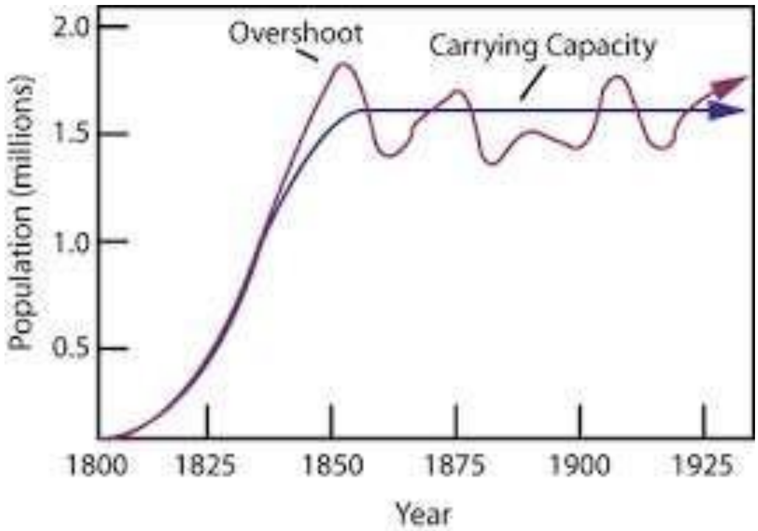
EXTENSION TASK Nº. 1

What happened around the year 2000 on the following graph?



EXTENSION TASK Nº 2.

Use the graph to answer the following questions**:**



What happened from around 1800 to 1850 on the graph?

What is the approximate carrying capacity on this graph?

What happened from around 1850 to 1925 on the graph?

EXTENSION TASK Nº 3

Do some research and write an essay about one of the following living beings. Write down in detail its ecology, habitat, ecological niche it occupies, its Latin name and add a photograph. Also, add at least two bibliographic resources. The text should be between 150 and 250 words.

Indian elephant

Scolopendra cingulata

Ginkgo biloba

Iberian lynx

6.8 ANNEX VIII

PBL Assessment: group work and research accuracy

CATEGORY	10	8	5	2
Ideas/Research Questions	The research is complete, with four or more interesting ideas that give depth to the resolution of the problem	The research is well formulated, with three or more ideas coherent with the resolution of the problem.	The research is coherent, but the teacher's help was needed to reach a conclusion.	The research is poor in content and lacks a coherent solution to the problem.
Quality of Sources	The research group has provided at least 4 reliable bibliographic sources	The research group has provided three important bibliographical sources and other unreliable sources	The research group has provided unreliable sources	The research group has not been able to provide quality sources of information
Distribution of responsibility in the group work	The group has divided the tasks equally and each member knows what the others are doing. Perfect communication.	The group has divided the tasks equally but only two are sure of what the others are doing, the others not so much.	In the group, one member distributes the tasks and supervises the work of the other members, there is a scarce sharing of responsibility.	In the group, two members work actively to carry out the tasks, but other members do not contribute at all. Destabilisation of the group. Poor communication.
Problem-solving	In the group, everyone comes up with ideas and each proposal is discussed equally.	In the group, some members come up with ideas, but everyone gets involved to discuss them.	In the group, some members propose ideas, the others do not show much interest, passively accepting the proposals.	In the group, the members do not manage to come up with common ideas and solutions to the problem.

PBL Oral Presentations Assessment

CATEGORY	10	8	5	2
Content	The student demonstrates a solid mastery of the topic.	The student demonstrates a good knowledge of the topic	The student has only partial knowledge of the topic.	The student hardly knows the basics of the subject, not even what belongs to his/her work group.
Speaks Clearly	The student speaks clearly and with consistency of scientific language and his/her words.	The student speaks clearly using his/her own words, with few mistakes in scientific language.	The student tries to use appropriate scientific language, uses his/her own words most of the time and must read some notes.	It is difficult to understand the student's oral expression.
Preparedness	The student is also prepared on the rest of the subject, not only about the contents of his/her groupwork.	The student has prepared his/her own topic but knows little about the relationship with the other topics.	The student defends his part but fails to connect with the other ecology arguments.	The student knows little about his topic and nothing about the rest of the ecology syllabus.
Attractiveness (Group mark)	The poster/presentation is exceptionally attractive in terms of design, layout, and neatness.	The poster/presentation is well designed and well organised. Easy to understand and follow.	The poster/presentation is acceptable but chaotic. Too many words in so little space.	The poster/presentation is a bit chaotic and difficult to read. The colours and layout do not make it easy to read.

The Mesocosm Experience report assessment

CATEGORY	10	8	5	2
Data collection and notebook.	The group has taken the experimental data every day; there are many photos and personal observations in the notebook. The members shared the task in a balanced and responsible way.	The group has taken the experimental data every day, there are pictures and shared the responsibility equally among the members of the group.	the group has not taken note of the experimental data every day, there is some picture but only two people in the team have been in charge.	A lot of experimental data is missing
Components of the report	The report is fully detailed, with extra ideas and observations that make the reading particularly interesting.	The report is fully detailed, all required elements are present.	The report is partially fulfilled, one required element is missing.	Several required elements are missing.
Lab attitude	The group has made full use of the laboratory, followed the experimental protocol in autonomy and respected the safety rules.	The group has made full use of the laboratory and followed the experimental protocol, but some members forgot to follow appropriately the safety rules.	The group needed the support of the teacher to move safely in the laboratory and to follow the experimental protocol.	Some members have not actively participated in the experimental protocol.
Investigative attitude	The group demonstrates a deep understanding of the rationale and usefulness of the IBL process	The group demonstrates that they have understood the main principles of the project and the usefulness of the IBL process	The group has completed the tasks but without a complete understanding of the implications of IBL process	The group has not understood the experimental approach and the implications of IBL process.

The Global rubric assessment

CATEGORY	CRITERIA	10	8	5	2
Direct observation	Attendance				
	Laboratory behaviour				
	Vocabulary accuracy and fluency				
Out-of-class tasks	Online tests				
	Extension tasks				
Productions	IBL Global Assessment				
	PBL Global Assessment				
Exam	Exam				